Using DITOPS as a Tool for Mixed-Initiative Schedule Improvement*

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1 Introduction

DITOPS is a transportation scheduling system based on the OZONE framework. OZONE [1] is a class library that provides primitive classes, methods and generic architecture for the rapid development of domain specific planning and scheduling systems. It is out of the scope of this paper to describe in details the internal behavior of the system and its algorithms. Refer to [2, 3, 4, 5] for more information.

In this demonstration we show that DITOPS is a tool that addresses, among other things, three main aspects of the planning and scheduling problem solving process:

1. Visualization of the problem and provided solution;
2. Iterative, mixed-initiative, improvement of the solution;
3. Reactive replanning and scheduling in face of external disruptions.

The problem we are solving here is the movement of cargo and / or passangers between two different locations or ports: we are given a situation, specifying the transportation resources available, and a number of move requests specified in the form of tpfdd records. The situation specifies the type, number, and configuration of the tranportation assets available for the operation. The move requirements specify: the type and amount of cargo to be moved; the origin and destination; the date the cargo is available to load – the *ALD*, the latest date the cargo can arrive – the *LAD*, and the earliest arrival date – the *EAD*. More details about the situations and move requirements are provided in sections 3 and 4. All the dates are represented as days from the beginning of the operation. The beginning of the operation is referred as day C0.

For this demonstration we have defined a scenario that is a subset of the 1994 Prairie Warrior exercise. We have reduced the number of assets and extracted around 400move requirements records from a large (17000 records) tpfdd file we have. After loading the situation and the move requirements into our system, we generate an initial schedule. Then we show how to use some of the DITOPS graphical user interface features to visualize the schedule and identify problems in it. After identifying the problems, we improve the solution by interacting with the system. Finally we show some reactive rescheduling when breakdown of resources are introduced.

2 Ditops User Interface

DITOPS design philosophy is based on the desire of providing the user maximum visibility of the solution generated, and maximum flexibility to change this solution, with the guarantee that the solution is always in a consistent state.

The system operation is event driven. All commands are available in the form of menus. The system responds to each command issued by the user. Loading files, creating different views, manipulating the schedule, and customizing the problem solving behavior are some of the high level commands available to the user. We will explain some of the commands as we proceed with our demonstration.

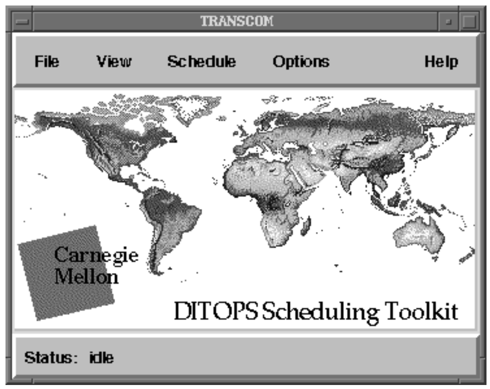

Figure 1: Opis Mainpanel

3 Load Situation

The situation is the set of resources available to solve the transportation problem we are presented. DITOPS does not make any *a priori* assumption about the resource availability and configuration. All information is loaded from a file. The situation file contains the general resource type descriptions, particular resource configurations for the problem, number of resources available of each type, and availability period. The situation we are using in this demonstration is in the file DEMO.SCENARIO. This file contains descriptions for ships, tankers, and airplanes. We will be using only airplanes in this demonstration. In our situation we have 5 C5s configured to carry 80 stons of cargo; 14 C141Bs configured to carry 22 passengers and 30 stons of cargo; and 8 C130s configured to carry 8 passengers and 13 stons of cargo.

The ports to be used are also part of the situation and are loaded before the transportation resources. We do not know in advance what ports would be used by the movements so we preprocess the entire tpffd file and load all required ports.

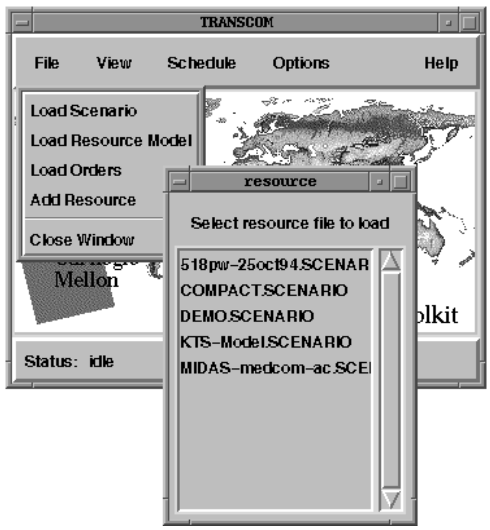

Figure 2: Load resources menu

4 Load Move Requirements

The move requirements are specified in a Cobol file in a format that we refer to as tpfdd records. These records specify all the information about the move requirements. One example of a tpfdd record is given below:

```
 ABDR   7AUS477CO TRANS LIGHT MDM TRUCK CO       218220
WAMYAA7724TLM.CO
00177001770000304000007400091560003928000019100000600000\
0000000000000000000606
HFTZ48C054BBNV48C057    LG              000
TVJDKSC072C076    00P          000 ESXMKSC080LD
00320940506940928                                    ABLBA
```

From these records we read the origin of the movement, the destination, the ALD, the LAD, the EAD, the type and quantity of cargo, and the mode. The ready date is the day the cargo is ready to be moved; we refer to it as the release-date. The due date is the latest date the movement should be completed. The preferred date is called earliest-arrival-date and we try to enforce it if possible. The mode can be *sea* or *air.* We consider 6 different types of cargo: *bulk, oversize, outsize, pax, pol,* and *break-bulk.* Each resource has different cargo capabilities, e.g. there are some resources that carry only pax (passengers), others carry only pol. Break-bulk and pol are used only for sea movements. The file we are loading, DEMO.SCENARIO, has only air movements. The move requirements we are using have been extracted from a large tpfdd file used in the Prairie Warrior exercise. The amount of cargo to be moved is: 308 passengers, 2748 stons of outsize cargo, 3909 stons of bulk cargo, and 2288 stons of oversize cargo. These move requirements use 12 different airports.

From the file menu, there are several different possibilities of loading a scenario. We can choose to load the entire scenario at once, or load the resources and the move requirements as separate steps. As OZONE is a generic scheduling tools, we refer to the move requirements by the generic term *orders.*

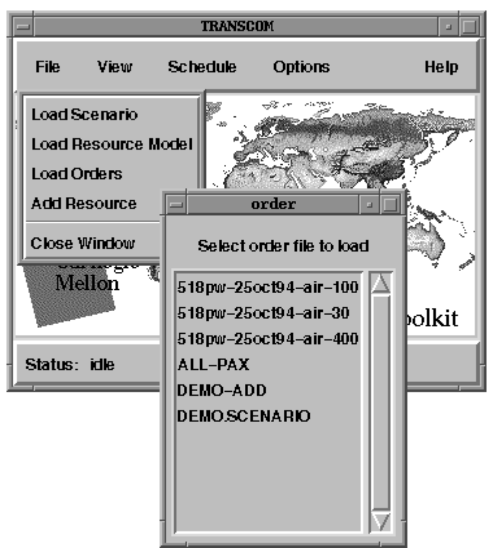

Figure 3: Load orders menu

5 Create Resource View

Once the situation and the move requirements have been loaded, several different ways of inspecting all this information are available. Graphical views of resource utilization at different levels of aggregation, views of the move requirements, text reports, and different kinds of graphics reports are some of the visualization tools provided. We will present some of these views in the next sections.

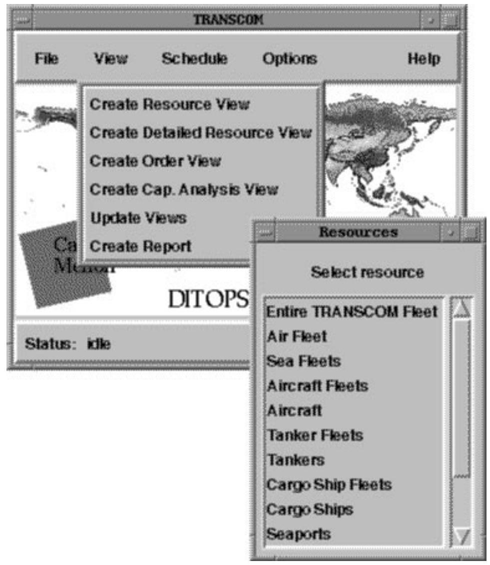

Figure 4: Create Resource View Menu

6 Aircraft Utilization View

After loading the scenario, we generate the deployment schedule. To satisfy a move requirement, one or more trips between specified origin and destination are scheduled. Figure 5 shows the resource utilization over time. In the first line, in the gray region just below the menu bar, we have the current time, and in the white region we have the time line expressed as days after the beginning of the operation. Each line below the time line represents one aircraft. The resource identification is written in the gray button on the left column. The height of each white line on the right represents the resource total cargo capacity. Each rectangle represents a trip performed by the resource: the left edge of the rectangle denotes the start of the resource loading at the port of origin; the right edge, the end of the resource unloading at the destination airport; and the height of the rectangle denotes the amount of resource cargo capacity actually used by the trip. The white spaces represent idle time or return trips that are not of interest. The light gray rectangle at the beginning of the time line corresponds to resource unavailability.

By using the mouse and the resource window menu we can manipulate and inspect trips and resources in several different ways. See figure 15 for the set of available resource window commands. In the view below we have selected one particular trip and created a textual description of it. The selection is represented by the black box surrounding the trip. The selection mechanism allows the manipulation or inspection of the entire set of object contained in the interval of time surrounded by the selection box. In the example, we can see that the trip is carrying 30 stons of bulk cargo and 21 passangers from Kimpo International to Campbell Air Force Base. The trip starts at 8:00 o'clock of day 3 and finishes at 12:00 am of day 4.

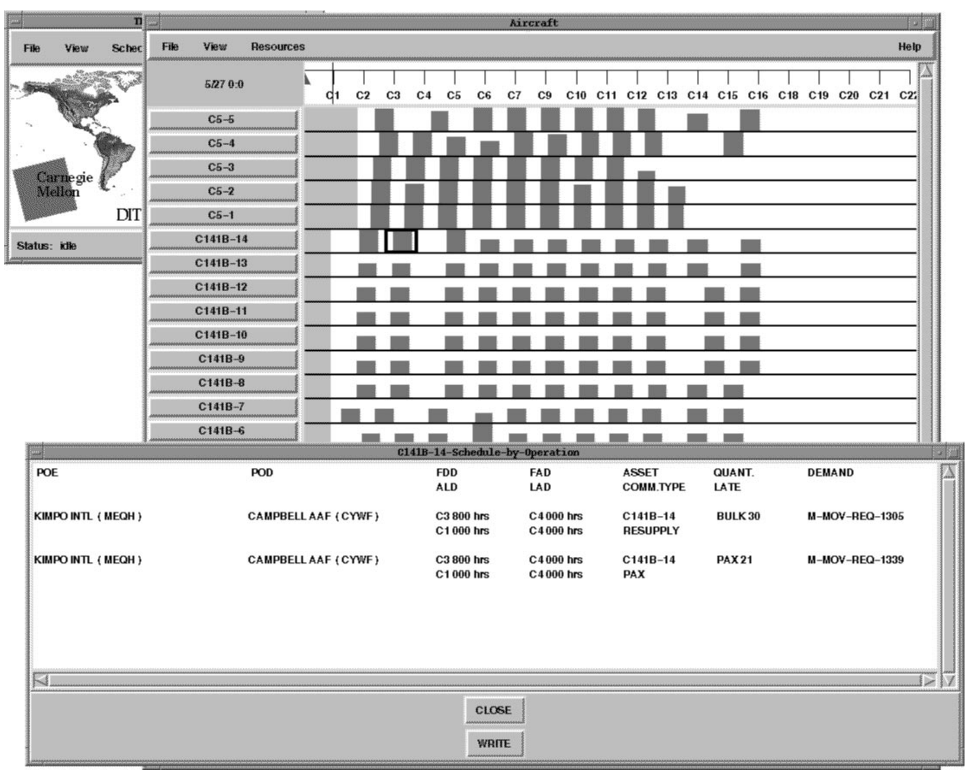

Figure 5: Aircraft Utilization View

7 Aircraft Utilization by Cargo Type

Resources have different types of cargo capabilities and move requirements specify different types of cargo to be moved. When the number of move requirements is really large, additional visual information on how the different types of cargo is being transported is needed. Figure 6 shows the different types of cargo in different colors. This view is useful to identify ways of improving schedule quality.

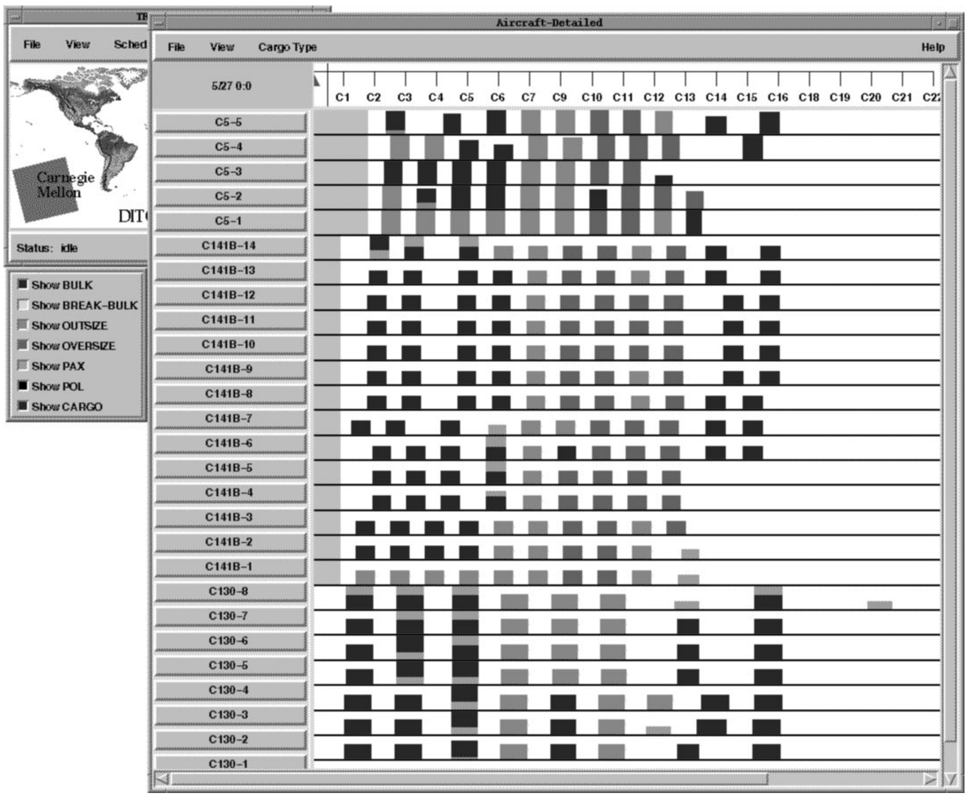

Figure 6: Aircraft Utilization by Cargo Type

8 Move Requirement View

The aircraft utilization views give us visual information about the resource utilization – they basically show us capacity constraints. However, they provide little information about the move requirements. Most of the time constraints, like release and due date, are associated to the move requirement descriptions.

The order window provides the visualization of time constraints associated with the move requirements. Similar to the resource window, the order window has the current time and the time line in the first line. The left column buttons are the move requirement identifications. The rectangles left and right edges represent movement release and due dates respectively. The triangle inside the rectangle is the earliest arrival date – the tip of the triangle is the earliest arrival date. The black I-beams represent the interval of time in which the movement has been actually scheduled. If the right edge of the I-beam falls outside the dark rectangle, the movement is late. As we can see in the center of the order view, several of the movements are late.

The selection mechanism also works on the order window. We have the ability of selecting a move requirement and inspecting or manipulating it. In the example, we selected the second move requirement from top and created a textual description of it.

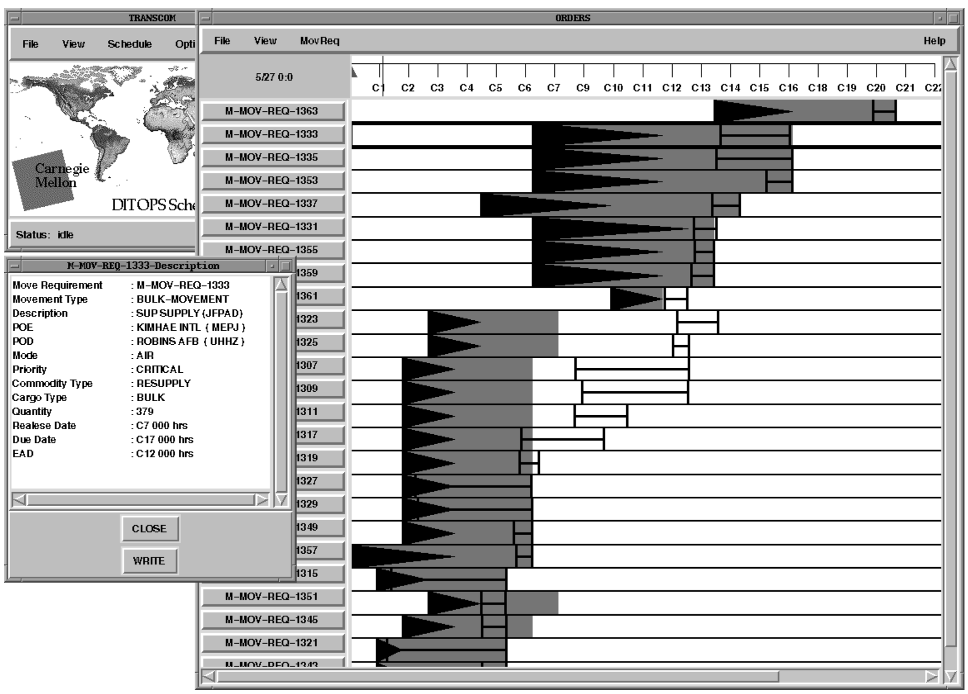

Figure 7: Move Requirement View

9 Airport Utilization View

In the same way we were able to see the aircraft utilization in figure 5, we can see the airport capacity utilization. Each trip uses the origin airport for the duration of the load, and uses the destination airport for the duration of the unload. We model airport capacity in terms of *maximum-on-ground.* We only allow a maximum number of planes to be loading/unloading at the same time. Airport capacity limitations are considered during the scheduling process. Figure 8 represents the airport capacity and the load and unload processes that are using it.

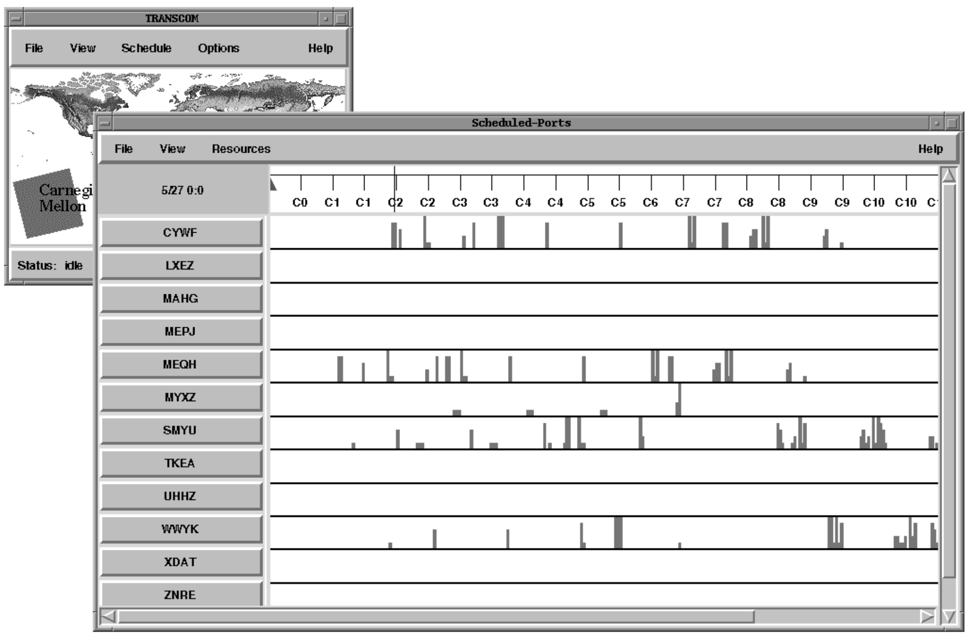

Figure 8: Airport Utilization View

10 Tonnage Graph

We have already looked at the capacity utilization of planes and airports. We have also seen the time constraints represented in the move requirement window. All we know until now is that some movements have been scheduled late. Some more detailed information about the schedule quality may be required.

The information about the schedule quality can be obtained from several different types of reports. Statistics and schedule summary reports can be created on demand. Graphical descriptions of the solution are also available. Figure 9 shows two of these graphical reports: the *lateness histogram* shows the number of late movements and the amount of lateness; the *tonnage graph* shows the cummulative delivery of cargo over time. The black line represents the actual delivery date, and the two lighter lines represent the earliest arrival and due dates. The ideal situation would be to have the black line between the two lighter lines. If the black line falls below the second lighter line, this means that cargo is being delivered late. As we can see from the tonnage graph, after day 7, the deliveries start to get late.

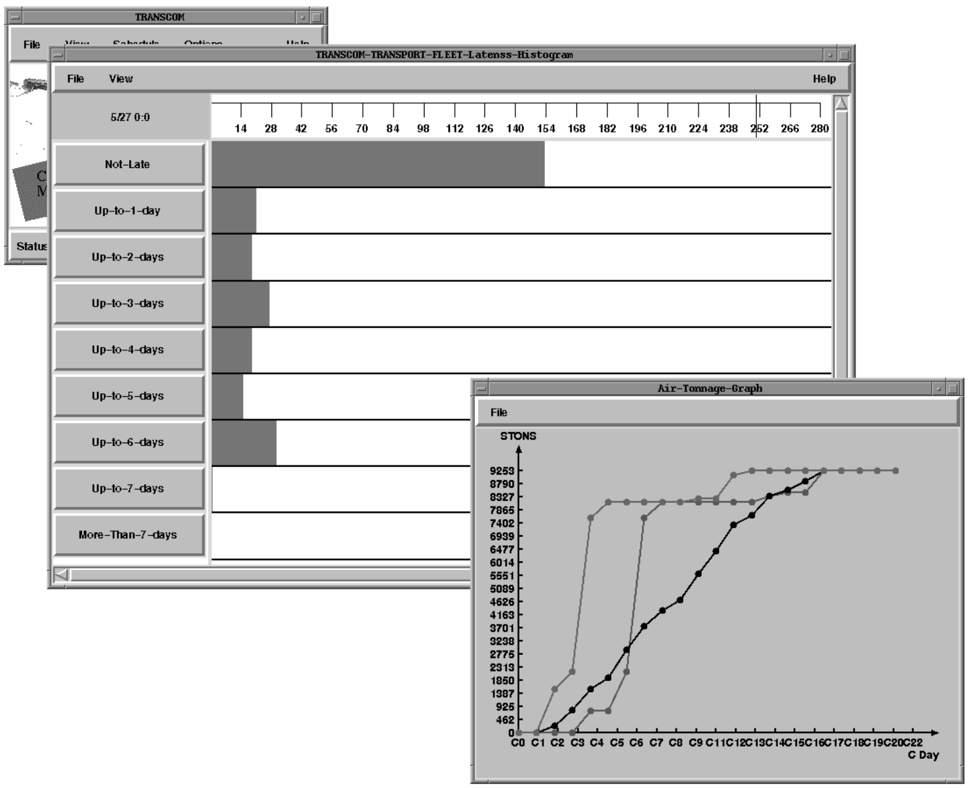

Figure 9: Tonnage Graph for Initial Schedule

11 Critical Lateness Coloring

By looking at the move requirement view we identified that there is a problem with the schedule. By looking at the reports we quantified the problem. Now we have to locate the cause of the problem. We already know that some orders are not getting at the destination on time. It would be nice if we could identify in the resource view and airport view wich are the trips that are late and how late they are. This is accomplished by the critical lateness coloring. DITOPS user interface uses different colors to represent trips that are on time, trips that are late, and trips that are critically late. By late here, we mean any trip that finishes after the required due date. Critically late trips are those that finish after a specified lateness threshold. DITOPS have a critical lateness slider that allow us to set this threshold. In figure 10 the threshold is set to four days. All trips that are more than three days late are colored in a dark color (red if you have a color picture.) From the figure, we can see that most of the operations between days 9 and 14 are critically late.

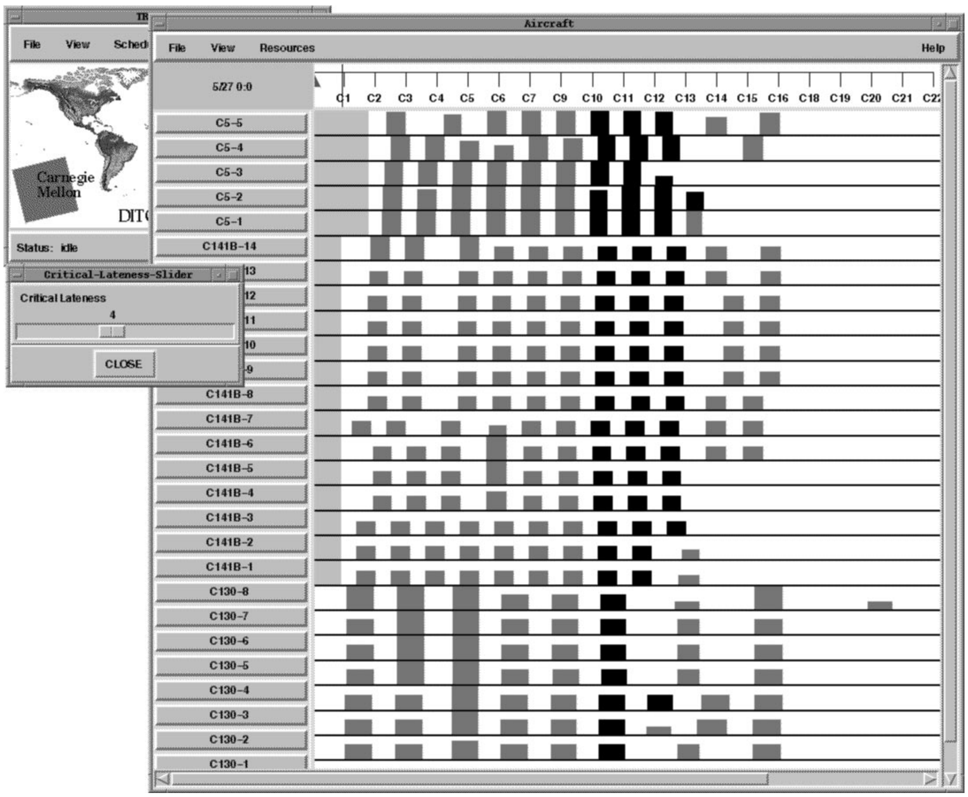

Figure 10: Critical Lateness is equal to 4 days

12 Add C5s to the Fleet

By looking at figure 6 and figure 10 we can see that most of the critically late trips are mainly trips carrying bulk, overzize, and outsize. There are no late passengers. This lateness can be attributed to insufficient lift capacity or to insufficient port capacity. By looking at figure 8 we can see that although there are some intervals in which the port capacity is used to its maximum, there are a lot of empty spaces. Therefore, we concluded that our problem is caused by insufficient lifter capacity. To solve this problem, we will add some airplanes to our situation. Assume that we can, for a reasonable price, use 5 additional C5s during the first two weeks. DITOPS interface allows the addition of resources without disruption of the schedule. Figure 11 shows the interface for adding resources. We are adding 5 C5s that will be available from day 2 until day 15. Figure 12 shows the aircraft view with the added resources. Notice the availability interval for the added resources.

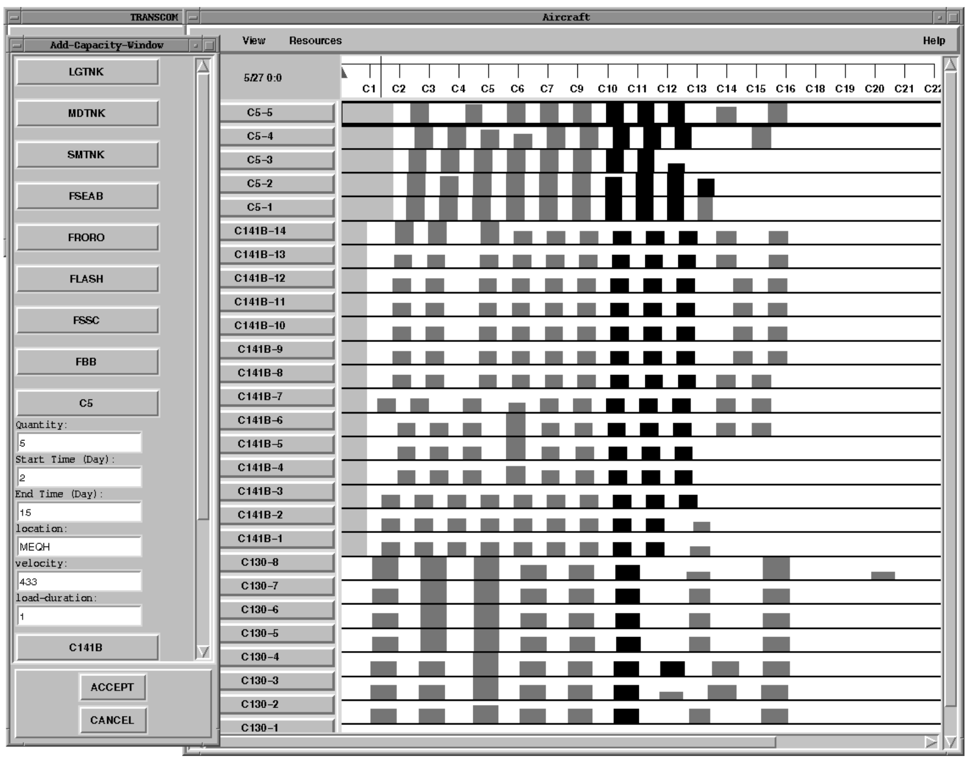

Figure 11: Window for adding resources

13 Aircraft Fleet View

One of the principles behind the DITOPS mixed-initiative approach to scheduling is minimizing schedule disruption. We have already added some C5s. It is not desirable to regenerate the entire schedule since we have already generated several resource commitments. We would like to selectively unschedule and reschedule trips or move requirements. We will show how we can do this using DITOPS flexibility.

As we can see in figure 12, several of the trips already scheduled on C5s are late. Since we have added some C5s, maybe it is possible to reduce the global tardiness on the C5 fleet. To do that we create the aircraft fleet view. This view is similar to the aircraft view but presents capacity utilization for the entire fleet. We can also select an interval in the aggregate view, and unschedule all the trips or only the critically late trips in the selected interval.

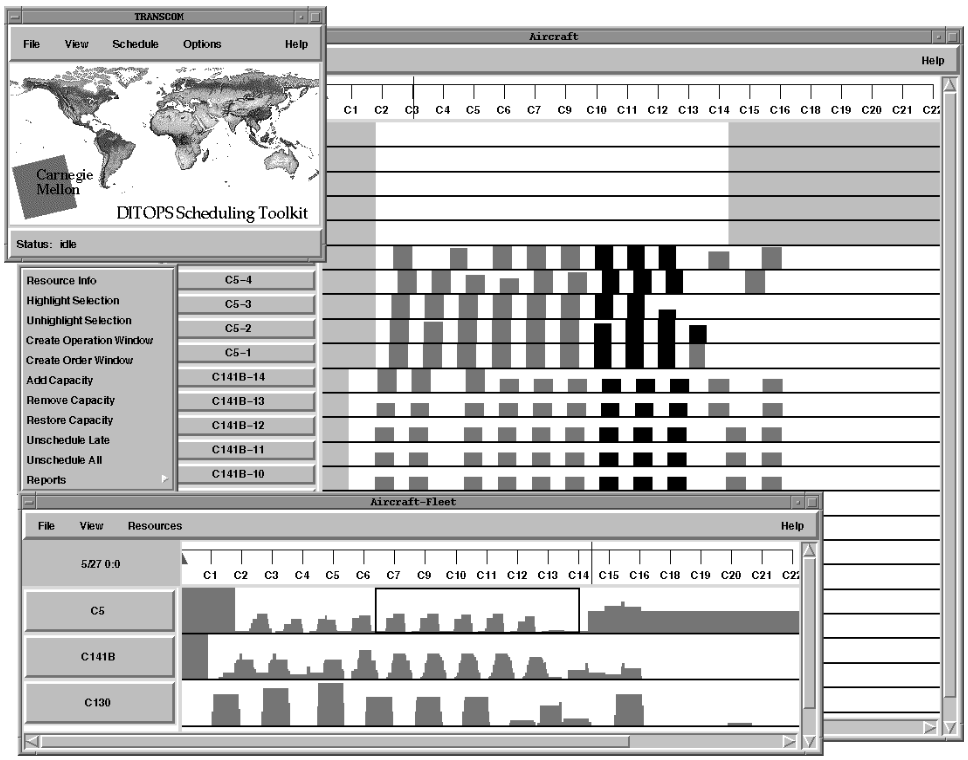

Figure 12: Aggregate Resource Utilization

14 Unschedule Late Movements on C5 Fleet

From the aggregate resource view, we selected an interval in the C5 fleet capacity representation, and unscheduled all the critically late operations in the selected interval. The light color indicates that the trips have been unscheduled. The unscheduled trip "footprints" are there only to show the modficiations in the state of the schedule.

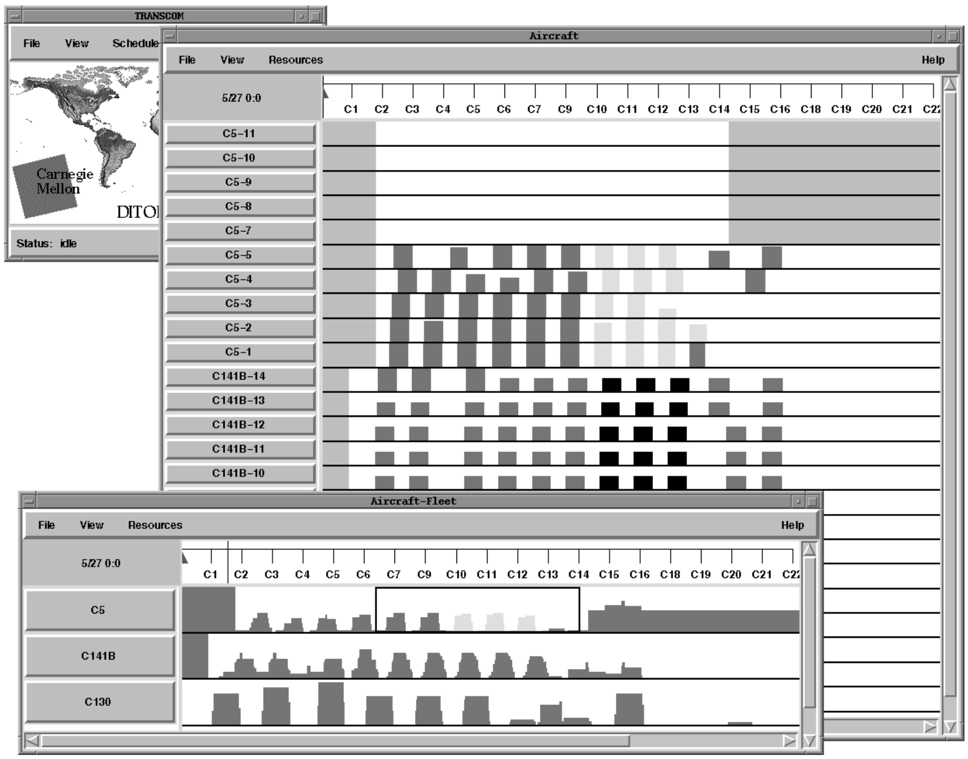

Figure 13: Critically late movements on C5 fleet unscheduled

15 Reschedule Late Movements using new C5s

After unscheduling the late trips on the C5 fleet, we reschedule them. As we can see in figure 14 all the trips are now scheduled in the added C5s and none of them are critically late.

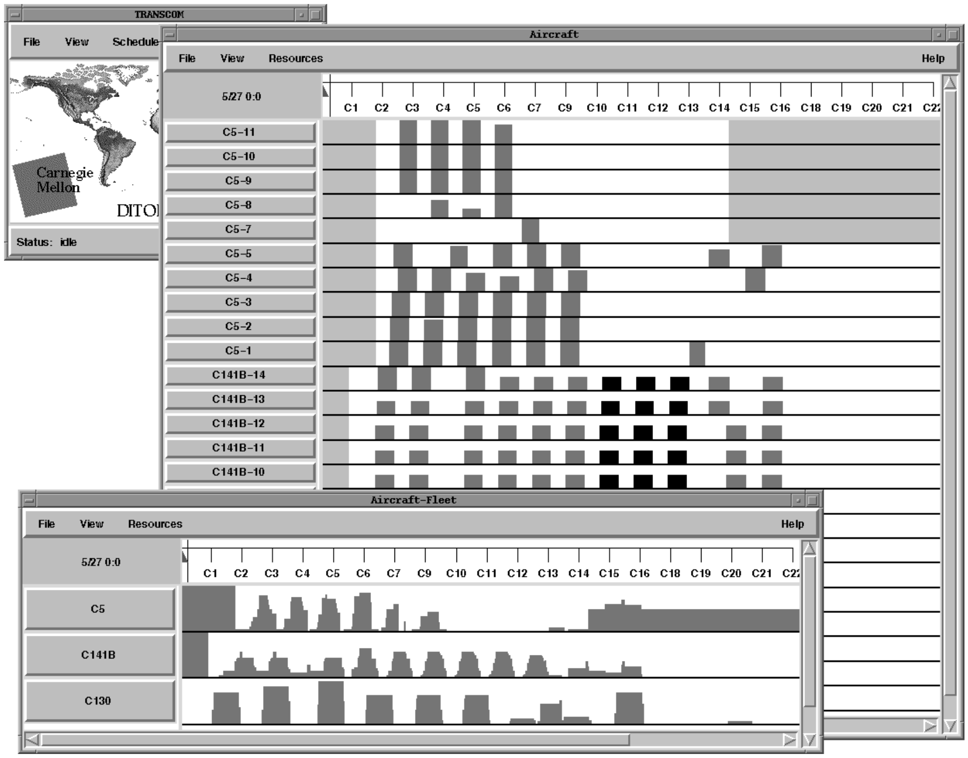

Figure 14: Critically late movements rescheduled on added resources

16 Select Trip on Aircraft View

After unscheduling the critically late trips, we notice that only one trip has been scheduled on plane C5-7. This means that maybe we do not need the additional C5. Maybe only four would have been enough. We proceed here by inspecting the trips on airplane C5-7. Figure 15 shows the trip selected on resource C5-7 and the set of commands available from the resource window. We choose the command to create the order window for the selected trip(s).

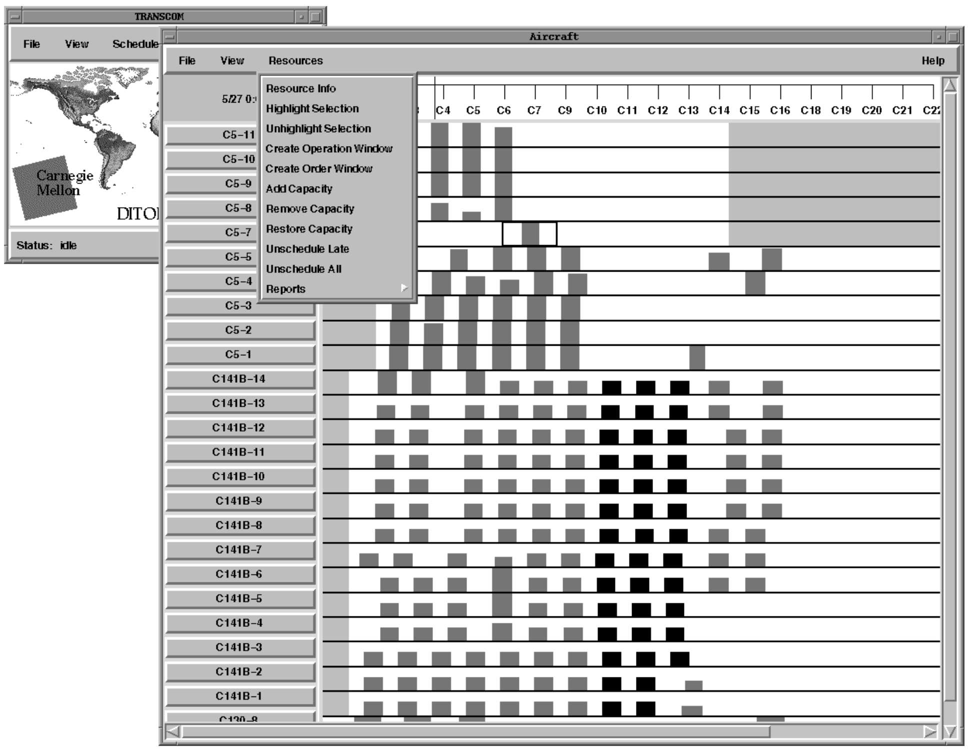

Figure 15: Trip selected on aircraft view

17 Show the Move Requirement View for the Selected Trip

The order window for the selected trip contains an expanded view of all the move requirements that have any trip contained in the selected region. In the case of our selection, the trip corresponds to only one move requirement. Figure 16 shows the move requirement for the selected trip and all the trips scheduled to satisfy the requirement. The lighter rectangle in the move requirement view is the trip selected in the aircraft window. The expanded move requirement view shows how the request has been split. It also shows that it is late.

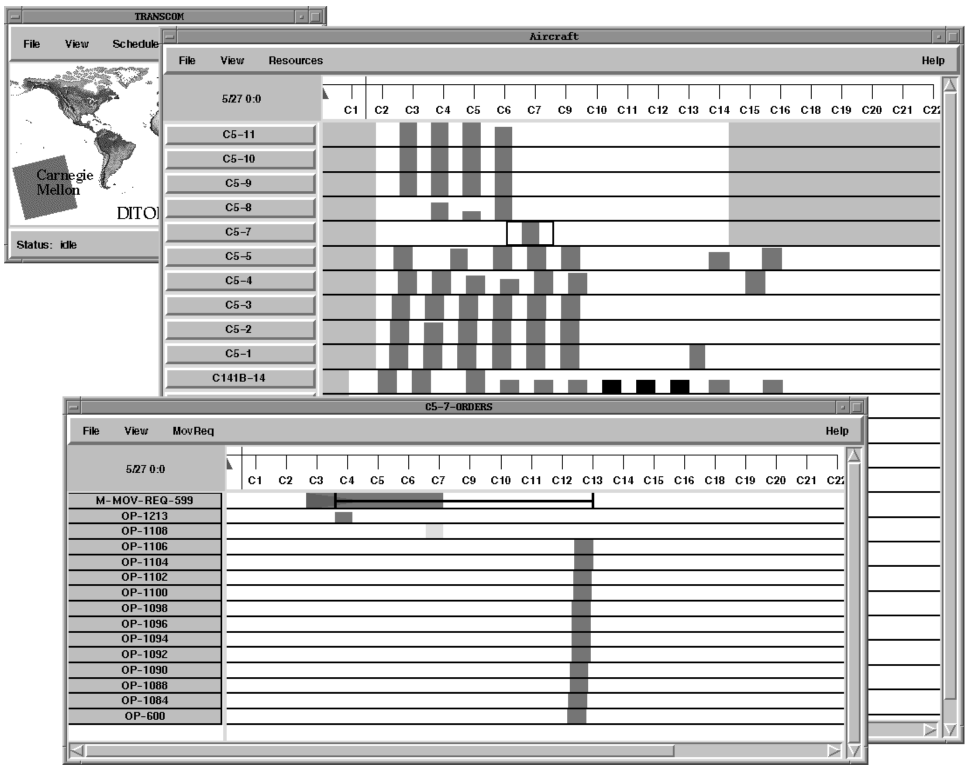

Figure 16: Move Requirement view of the selected trip

18 Select Move Requirement in Move Requirement View

In the same way we selected the trip in the resource view, we can select any object in the expanded order view. Several commands are available in this view also. Here we want to show the capability of visualizing the order in the aircraft window. We choose the command “Highlight Selection,” and later we will choose “Unschedule Order.”

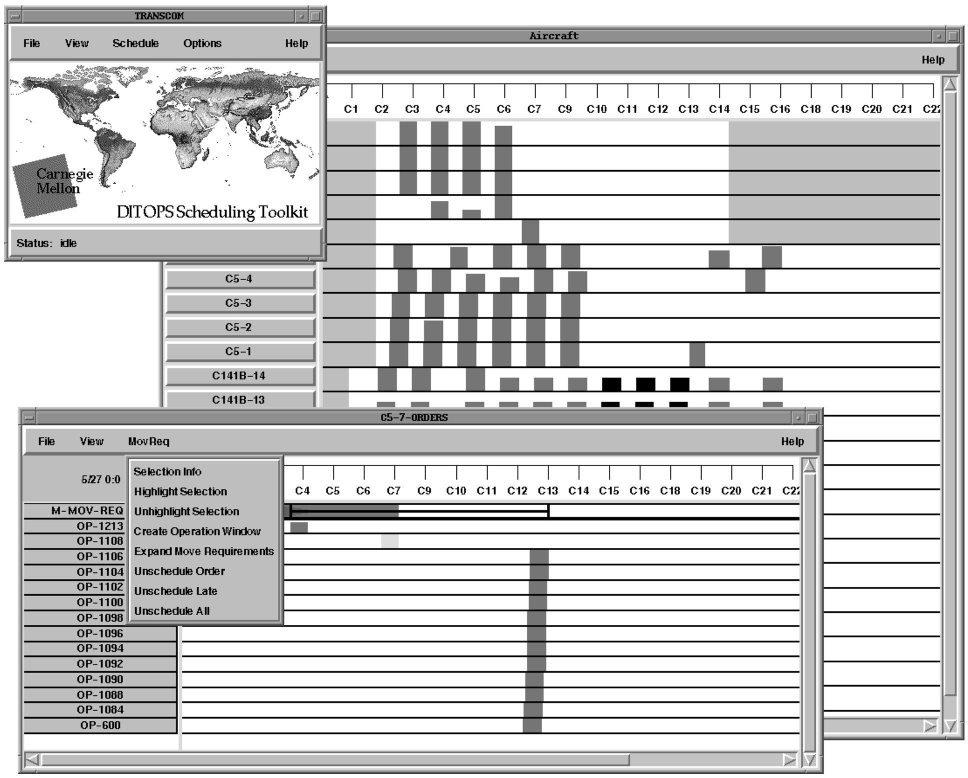

Figure 17: Move Requirement Selection

19 Highlight all Trips of a Selected Move Requirement

Figure 18 shows in lighter color all the trips that have been scheduled to satisfy the move request selected in figure 17. Notice that there are several trips on C141s and these trips are all late.

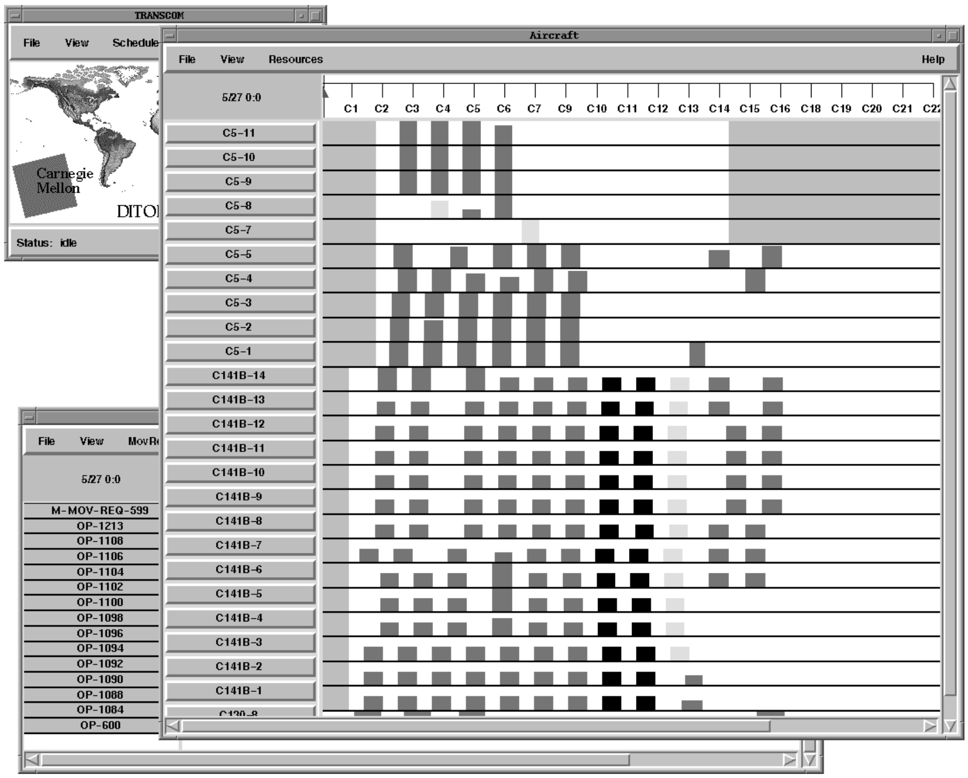

Figure 18: All the trips of the selected Move Requirement

20 Unschedule Selected Move Requirement

The selected move requirement of figure 17 has been mostly scheduled on C141s. We can see that there is still C5 capacity available that could eventually be used by this movement. DITOPS interface allow us to unschedule and schedule only the selected move requirement. Figure 19 show the schedule after unscheduling the selected move requirement.

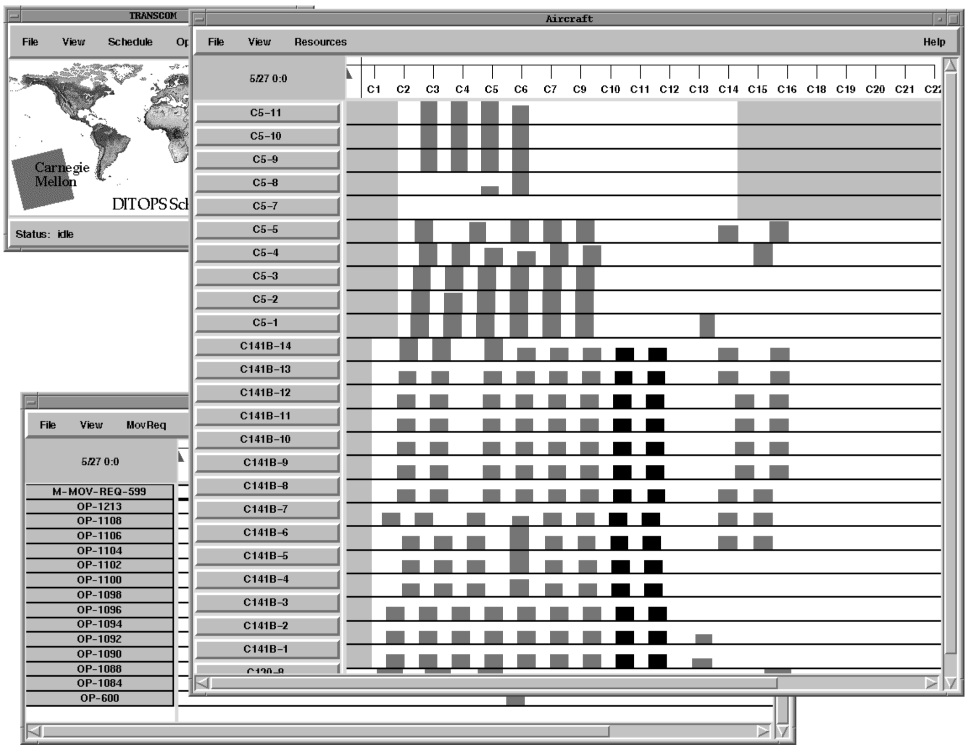

Figure 19: All trips of selected Move Requirement have been unscheduled

21 Reschedule Selected Move Requirement

Figure 20 show the same selected move requirement of figure 17 after being rescheduled. Notice that the movement has now been scheduled on the added C5s and the amount of splitting and lateness has decreased considerably.

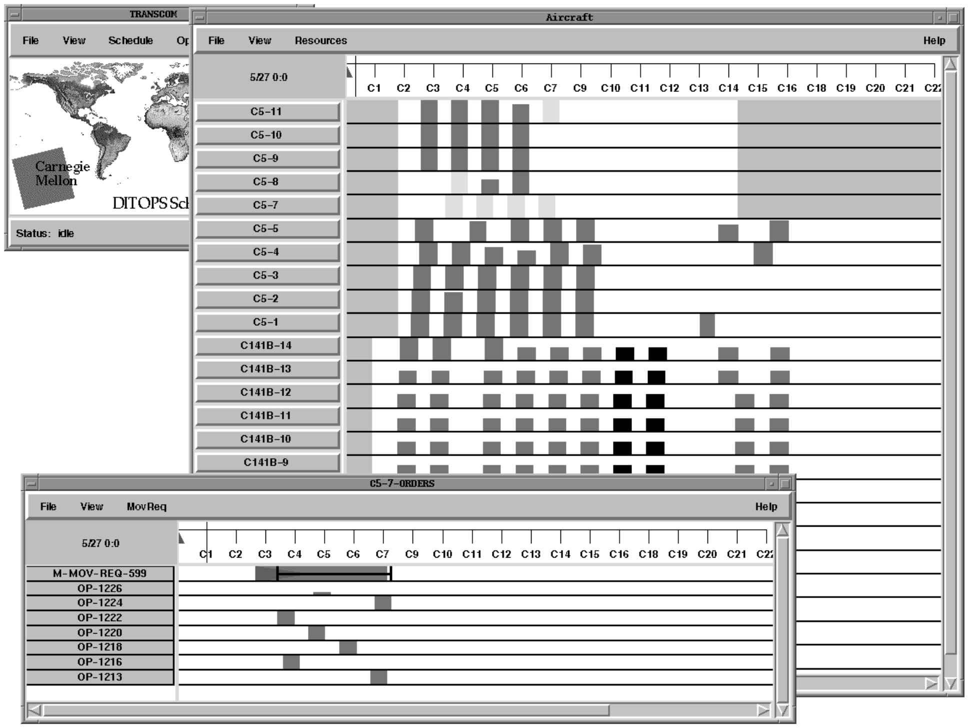

Figure 20: Unscheduled trips have been rescheduled

22 Unschedule Remaining Critically Late Move Requirements

After doing some selective repair, we will do a more drastic one: now we unschedule and reschedule all remaining critically late trips. From the main panel "Schedule" menu we select the command "Unschedule Late." The result after the unscheduling is in figure 21.

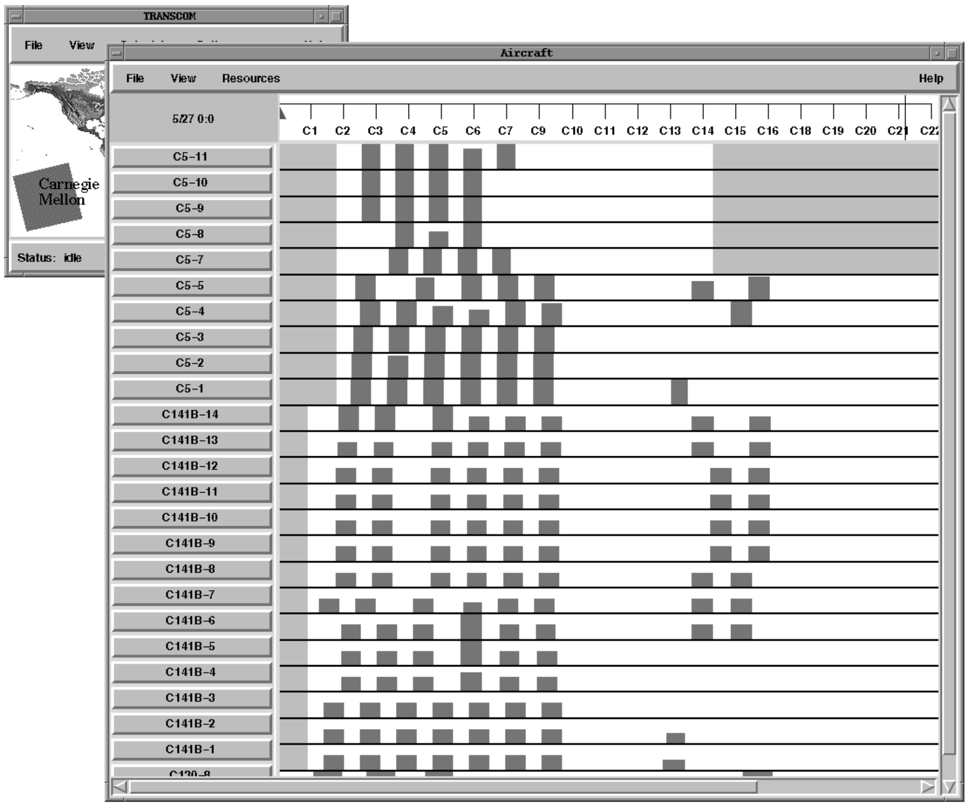

Figure 21: All critically late trips have been unscheduled

23 Reschedule Remaining Critically Late Move Requirements

Figure 22 shows the schedule after rescheduling all remaining critically late trips. As we cann see now, there are only two trips that are critically late.

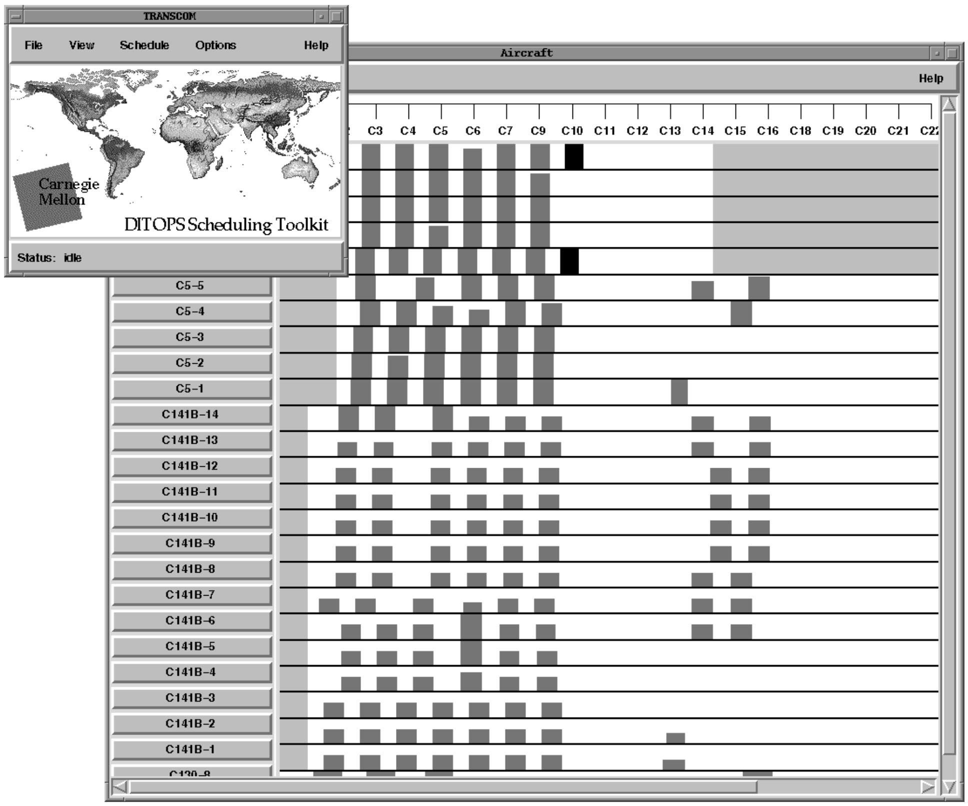

Figure 22: Unscheduled trips have been unscheduled

24 Graph Reports After Major Rescheduling

Figure 23 shows the Lateness Histogram and the Tonnage Graph after all the changes we have made to the schedule. Compare to figure 9 and see the improvement. There are still some late trips but they are less than four days late, which is the critical lateness threshold we have initially set.

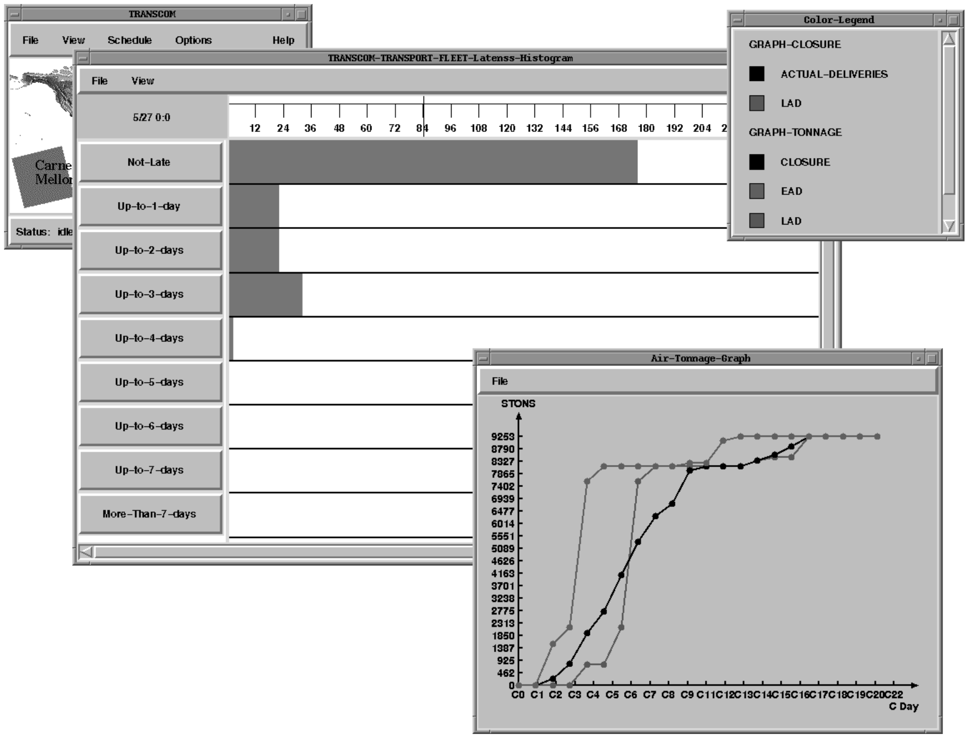

Figure 23: Tonnage Graph and Lateness Histogram after Rescheduling

25 Move Time and Make Resource Unavailable

In the previous section we have shown ways of improving the quality of the schedule. In the following sections we will show how to repair the schedule with minimal disruption as unexpected events occur.

Assume that we have been operating our system without problems and now we are on the fifth day of our operation. The little triangle on the time line window represents the current time. By dragging the triangle we can move the current time. In figure 24 we have moved the triangle to the position C5. In the gray area, the value of the current time gets updated. For some reason, on day 5, airplane C141B-14 becomes unavailable. Notice the light gray rectangle denoting the resource unavailability and the dark rectangles inside representing the conflicts.

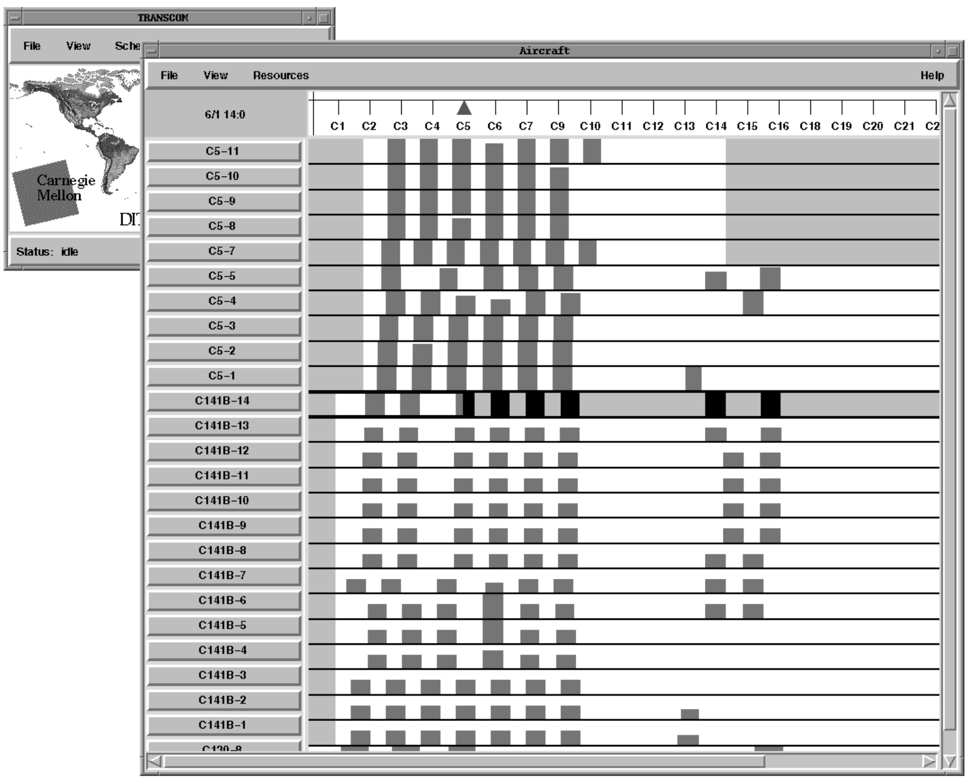

Figure 24: Current time is day 5 and aircraft is removed

26 Reschedule after Resource Breakdown

After the breakdown, the scheduler is called to fix the conflicts and some of the trips that were on airplane C141B-14 are now on airplanes C5-9 and C5-10.

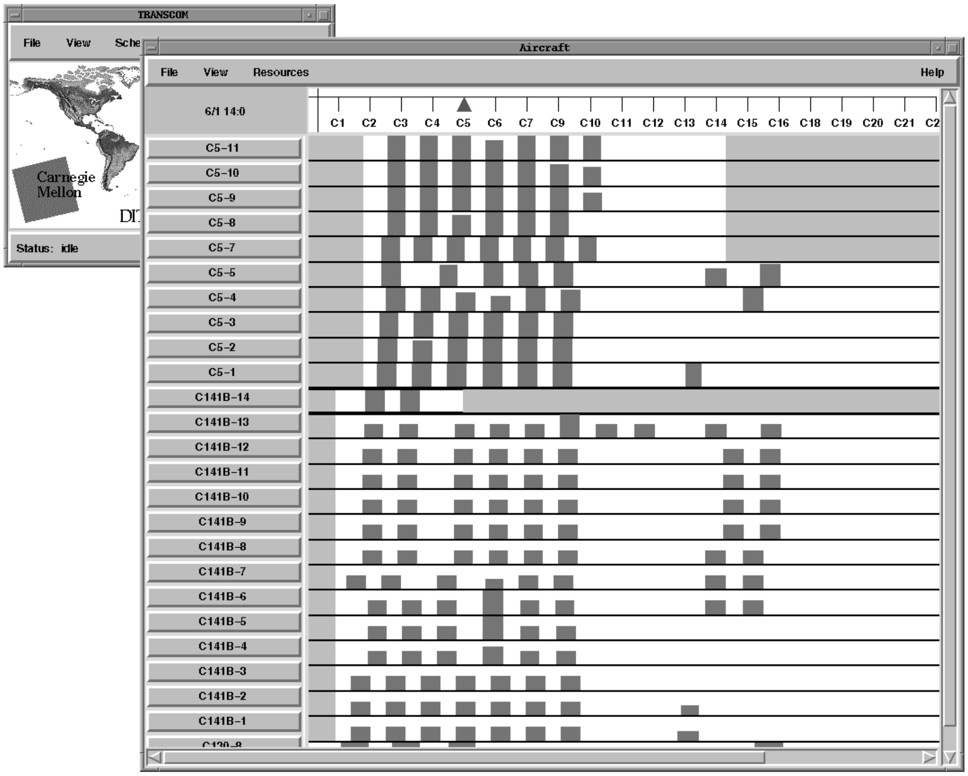

Figure 25: Trips scheduled on removed resource have been unschedule

27 Close a Port for some Period of Time

To illustrate a more complex reaction, we will close an airport port for some period of time. We close Campbell Air Force Base (CYWF) for almost one day. As we have moved time, the airport window is created starting from the current time. Similar to the aircraft case, the resource unavailability is denoted by a light gray rectangle and the conflicts by dark rectangles inside.

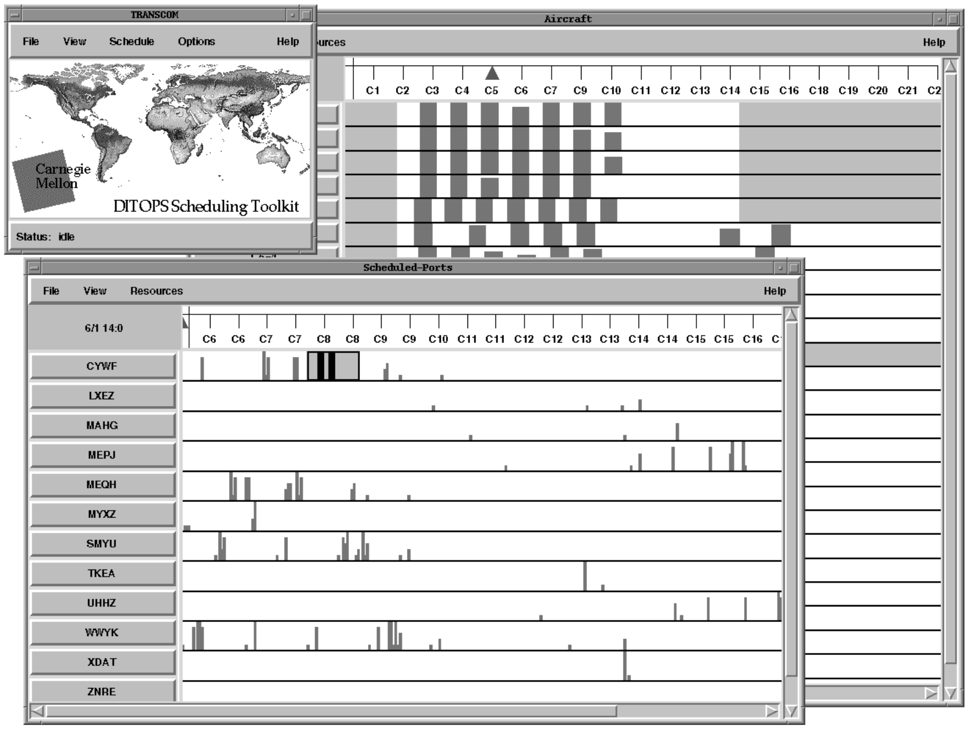

Figure 26: Airport is closed for some time

28 Reschedule Trips Arriving/Leaving Closed Airport

After calling the scheduler to solve the conflicts, we can see that the conflicts have disappeared and most of the operations scheduled around day 7 have been shifted by some little amount of time. Compare the aircraft view of figure 27 with figure 24

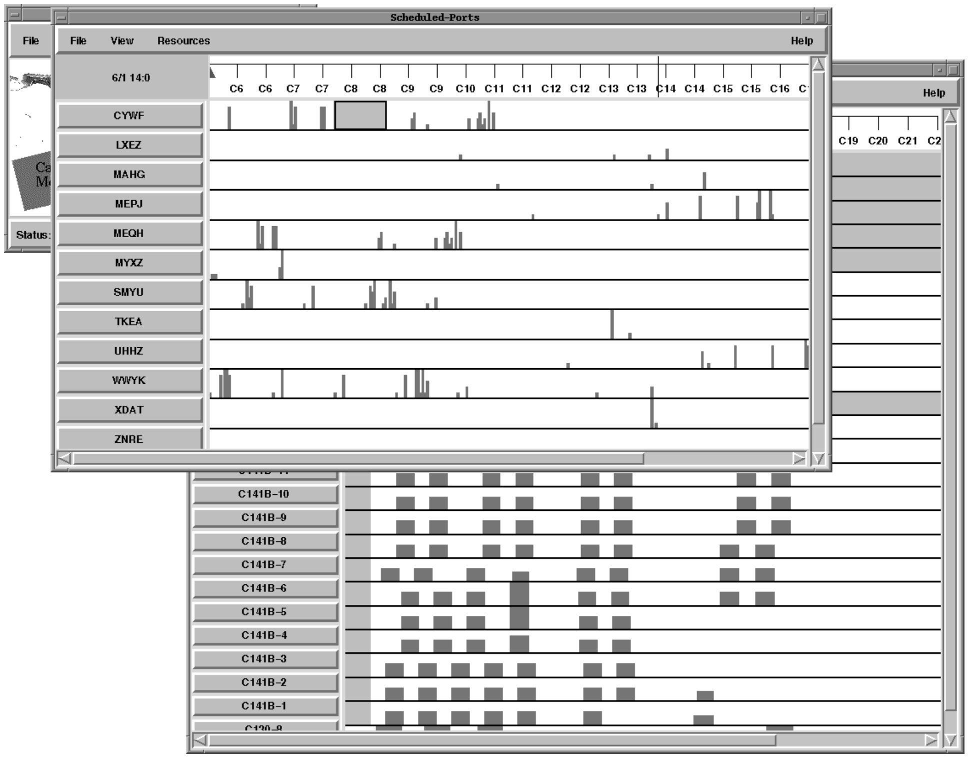

Figure 27: Scheduled trips have been adjusted

References

[1] Stephen F. Smith, Ora Lassila, and Marcel Becker, "Configurabke Mixed- Initiative Systems for Planning and Scheduling", in *Advanced Planning Technology*, (ed. A. Tate), AAAI Press, ISBN 0-929280-96-9, 1996.

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