LiU LINKÖPING
UNIVERSITY

Linköping University

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Communications and Transport Systems
Department of Science and Technology
Dr. Christiane Schmidt

Exam
Air traffic and air transportation
TNFL01
TEN1
02-01-2018

· Time: 14-18

· Number of questions: 8

· Total number of points: 80

· Grades: <40:UK, 40-53: 3, 53,5-66,5: 4, 67-80: 5

· Examinator: Christiane Schmidt

· Jourhavande lärare: Valentin Polishchuk, tel 073 6569219 (Christiane Schmidt, tel +46 (0)70 245 0380)

· Hjälpmedel: Räknedosor som ej kan lagra text, alt. med tömda minnen är tillåtna. Ordböker engelsa-svenska är tillåtna. Inga andra hjälpmedel.

· Results will be published latest on Janaury 16

Please note:

· Carefully account for your computations and solution methods.

· Give reason/facts/motivation for all your claims.

· Always use the standard methods as presented in the course.

· You will rarely get full points on a question by just reciting facts from literature and lectures; discussion, showing up connections and examples are necessary.

· You are allowed to use English-Swedish, Swedish-English dictionaries.

· You can write in either English or Swedish.

· Communications devices of any kind (phones, computers, etc.) are not allowed.

· You may use only one side of your paper for your answers.

· Use one sheet of paper for a single answer only.

· Use a maximum of an A4 page per question. In case figures and computations are included, you may use several pages.

· This exam consists of 5 pages.

· With 40 of 80 points you will pass the exam.

· You may not use a *red* pen for any written answers.

· You have 240 minutes to complete this exam.

· Sort your sheets of paper in the order of the given questions.

· Mark the problems you worked on on the envelope.

· Check how many papers you submit, and fill in the number on the envelope.

Problem 1: Crew rest time **10 points**

Pilot X works for airline FlyFast. Because of good contacts to the unions, FlyFast managed to negotiate few, simple rules for the rest periods of their pilots:

- Maximum 10 flight hours per day. Those 10 hours can be exceeded by maximum 2 hours. This holds only if the night rest is extended by $2\times$ extension. If the rest period in the night before was longer than 16 hours, up to 1 hour can be assigned to the night rest of the prior night with: $\min\{(\text{extra night rest night before})/3, 1\}$ hours.

- Minimum 16 hours rest between last flight of a day and the first flight of the next day.

- Maximum 40 hours flight within an arbitrary 7 day period.

- Minimum 24 hours time off (uninterrupted) at home base within an aribtrary 7 days period.

Pilot X had 9 flight hours on October 5, October 6-8 he had time off at his home base LHR, on October 9 he flew 5 flight hours, with the last flight ending at 14:00 UTC.
On October 10 he flew:

- LHR-MAD, 2h 30 min flight time, 07:00-09:30 UTC

- MAD-LHR, 2h 20 min flight time, 10:30-12:50 UTC

- LHR-FCO, 2h 30 min flight time, 13:30-16:00 UTC

- FCO-LHR, 2h 40 min flight time, 17:00-19:40 UTC

Unfortunately, FlyFast's pilot Y is sick on October 10. Amongst others he was scheduled to fly flight FF234, LHR-CDG, 1h 20 min flight time, 20:30-21:50 UTC. The crew controller plans that pilot X takes over flight FF234.

(a) According to the rules for rest periods: Is it possible that pilot X flies on flight FF234, is it a feasible pairing? If yes, what is the earliest time a flight he is scheduled for can depart on October 11?

Possible solution. The last two rules aren't influenced by the additional flight. The originally scheduled flights for X have a total of 10h flight time. According to the first rule this can be exceed by max 2 hours. 1h 20min = 80 min $<$ 2h, thus, it is possible to schedule X for flight FF234. In the night October9-October10, X had 17 h rest, this exceeds 16h by one hour, according to the formula $\min\{1/3, 1\}h = 1/3h = 20$ min can be assigned to that night. This leaves 1 hour to be charged to the night October 10-October 11, and it needs to be charged with twice its value: 2hours. Thus, X must have 18h of rest. Consequently, the first flight on October 11 for X could start at 15:50 UTC.

(b) If X is used on flight FF234, what other consequences result for crew planning?

Possible solution. X arrives at CDG, which is not his home base, a hotel night needs to be added. Moreover, X will not be at LHR on October 11, where his next flight would have started, either a dead-head flight needs to be planned, or he needs to get a new duty starting at CDG. Moreover, instead of 19:40 UTC + 16h = 11:40 UTC, he can now only start his next duty at 15:50 UTC. Possibly other pilots will receive a new duty to take over X's original flights from October 11, this may have further consequences for the crew planning for the following days.

Problem 2: No CDM   **10 points**

The airport Littletown has two runways with a peak capacity of 50 movements per hour. An incident resulted in one unusable runway. This limits the capacity to ca. 22 movements per hour for the foreseeable future. Within the next hour 27 arriving a/c and 22 departing a/c are expected at Littletown. Explain how the airport and ATC will handle the departing and arriving traffic, given that no system for Collaborative Decision Making is implemented at Littletown.

Max. one A4 page text!

Possible Solution.

As the runway capacity is not sufficient, some flights need to be delayed, alternatively, if possible, flights can be routed to close alternative airports and ground transport must be organized for the passengers.

Otherwise, arriving traffic is usually delayed by holding, in case it is not possible to reach the pilots to reduce speed (which is preferable both from an environmental and a cost perspective). Departing traffic can be delayed on the ground (without inflicting cost or environmental effects). Thus, it might be preferable to prioritize incoming traffic, and let the departing a/c wait. Prioritizing arriving flights also ensures that arriving pax and crew with flight connections manage to arrive in time before they need to start again. Before choosing this option it has to be checked whether enough space is available for all aircraft that will be located at the airport.

As the capacity is reduced it is also important that it is fully used. This can be achieved by sequencing the traffic such that the saftey margin due to wake vortex can be as small as possible.

For a longer time interval, NMOC will send out CTOT (slots) to flights that haven't started, but will land in Littletown, to reduce the pressure on the airport.

Problem 3: CDM   **10 points**

The airport Littletown has two runways with a peak capacity of 50 movements per hour. An incident resulted in one unusable runway. This limits the capacity to ca. 22 movements per hour for the foreseeable future. Within the next hour 27 arriving a/c and 22 departing a/c are expected at Littletown. Explain how the airport and ATC will handle the departing and arriving traffic, given that a system for Collaborative Decision Making is implemented at Littletown, and explain how the interaction with other players can turn out.

Max. one A4 page text!

Possible Solution.

Essentially, the management will be similar than without CDM, but it becomes easier for all players to influence the decisions of other players. For example, the airlines can send requests to the ATC which aircraft (both in the arriving and the departing queue) should be prioritized.

CDM includes a good system for information sharing at the airport. This includes that potential problems with many aircraft on the ground, poor control over where certain aircraft, or ground handling vehicles, are located, can be avoided.

In addition, such incidents results in the need of replanning for all players, for example, gate allocation, refueling, cleaning etc. With CDM this planning can be based on accurate data about the current

situation, and it can be communicated to other affected partners. For example, if an airline requests from ATC to prioritize a specific aircraft, they can send this information to the handling companies, who will then be ready at the gate.

The CDM procedure substitution on cancellation can be used, that is, airlines that have flights to Littletown that haven't started yet, and thus get an CTOT, will cancel their flights to Littletown and can still keep their slots at the airport.

Problem 4: Route network   10 points

An airline's route network is often a mix of pure hub-and-spoke and pure point-to-point systems. Discuss how an airline can exploit the advantages and avoid the disadvantages of those two extremal network types by using a mixed route network.

Max. one A4 page text!

Possible Solution.

One of the biggest advantages of a point-to-point system is that passengers appreciate travel without switching planes. By creating direct flights for important, profitable routes, an airline can obtain higher occupancy or yield.

To make use of the advantages of a hub-and-spoke system, like a common maintenance base, a common home base for the crew, etc., the network must be connected to the base, such that it is possible to have overnight stays there as often as possible. For a big airline it is an option to use multiple hubs, which reduces the network's vulnerability to a certain degree, in case the hub is affected by some incident. To be able to make us of the advantage of having many possible flights in a hub-and-spoke system, it is also important to temporally connect direct flights, such that is its possible to use them as connecting flights.

In general, it should first be identified which flights should be offered as point-to-point due to high demand, and then the rest of the schedule will be planned w.r.t. those fixed flights and w.r.t. the (one or multiple) hub(s). This combination will nevertheless result in a loss of robustness in comparison to a full point-to-point system: if one flight is disrupted, this will also affect other flights. So, it is not possible to simply obtain all advantages and to avoid all disadvantages at the same time.

Problem 5: Refueling   10 points

Refueling at Littletown lies within the responsibilty of BigFuel. BigFuel has two fuel trucks. They have the following jobs:

Flight Nr.	Earliest start	Must be finished at	Estimated refueling amount in kg
1	6:00	6:25	6000
2	6:10	6:25	1200
3	6:10	6:35	9000
4	6:20	7:00	4800
5	6:50	7:15	4200
6	7:10	7:55	12000
7	7:40	8:10	1800
8	7:30	8:10	9000

The smaller truck has a volume of $10m^3$, the larger truck has a volum of $15m^3$.

The estimated time to move from one aircraft to another, or between an aircraft and the depot, where the trucks can refuel, is 5 minutes.

Both vehicles can be used for a single flight, though at any point in time only one vehicle can be actively refueling this aircraft.

The refueling process can be performed with $1m^3$ per minute, both for the aircraft and for the vehicles at the depot.

The fuel density is $0,6$kg/liter.

Visualize the jobs with a gantt chart. Decide how the two trucks should serve the eight flights. Discuss advantages and disadvantages of your solution.

Possible Solution.
The larger truck has a capacity of 15000l, the smaller of 10000l. The density is 0.8kg/liter, thus the required amounts for the flights are: flight 1 10000l, flight 2 2000l, flight 3 15000l, flight 4 8000l, flight 5 7000l, flight 6 20000l, flight 7 3000l, flight 8 15000l.
Thus, the refueling time for, for example, flight 1 is 10 minutes.
The gantt chart, Figure 1, shows the starting and end times of refueling processes and of driving. Red indicates the small truck, green the large truck. The indicated times show start and end times.

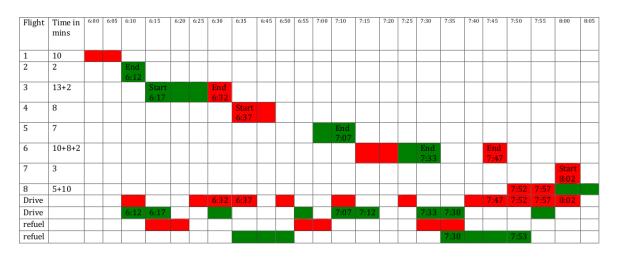| Flight	Time in mins	6:00	6:05	6:10	6:15	6:20	6:25	6:30	6:35	6:45	6:50	6:55	7:00	7:10	7:15	7:20	7:25	7:30	7:35	7:40	7:45	7:50	7:55	8:00	8:05
1	10	■	■																						
2	2			End 6:12																					
3	13+2				Start 6:17			End 6:32																	
4	8								Start 6:37																
5	7												End 7:07												
6	10+8+2																	End 7:33			End 7:47				
7	3																							Start 8:02	
8	5+10																					7:52	7:57		
Drive								6:32	6:37												7:47	7:52	7:57	8:02	
Drive				6:12	6:17									7:07	7:12			7:33	7:38						
refuel																									
refuel																		7:38			7:53			

Figure 1: The gantt chart shows when which truck serves which flight. In some cases both trucks are needed for a single aircraft. Black times indicate start and end times.

In the presented solution all flights are served in time. Sometimes there is no buffer time, e.g., flight 8 is served until 8:10. Any delay will then result in a delay of the entire turn-around process.

Problem 6: Maximize Yield   10 points
You get hired by a new airline, AirSweden, to make sure that they operate with a profit. The owner

of AirSweden, Mr. A, has heard other airlines talking about yield, and now suggests to maximize the yield. Explain to Mr. A what yield is, and detail why it is not a good idea to solely aim for maximizing the yield.
Max. one A4 page text!

Possible solution:
The yield constitutes a nominal unit income: the income per passenger (pax) kilometre. Assume we consider only a single flight leg of 1000 kilometres, with 65 passengers, each paying 3000 SEK for the ticket. The passenger revenue for this flight leg is 65*1800=117 000; the revenue passenger kilometer (RPK), that is, the number of paying pasesngers transported for one kilometer, is 65*1000=65000. The yield is then defined as the ratio of passenger revenue and RPK, thus, for our example, the yield is 117000/65000=1.8.
As your job descrition states, you should help to operate AirSweden profitable, and, as any other airline, AirSweden will have to maximize its profit to do so. The profit is defined as Operating profit = RPK*yield - ASK*unit cost (income minus cost), where ASK denotes the available seat kilometers, that is, the number of availabe seats flown for one kilometer, and the unit cost is the ratio of total operating expense and ASK.
If AirSweden now maximizes the yield, this might be obtained by only a few passengers paying a very high fare and leaving a large portion of seats unused. This results in a low load factor (ratio of RPK and ASK) and, consequently, low total revenues that do not cover all operating expenses. In this scenario AirSweden would have a high yield, but actually not operate with profit, or at the very least not maximize the profit. Thus, such a one-sided strategy should not be followed by AirSweden.

Problem 7: Dichotomy of Demand   10 points
You are working for a large, international airline. In conversation with a representant of a large dairy company at a conference, said representant asks you to quantify demand and supply on the route Arlanda-Newark. He is surprised to hear that you cannot easily quantify the demand and supply, as he easily can for, for example, milk with 3,25% fat in Stockholm in January. Give the dairy representant a detailed explanation on dichotomy of demand and supply in the airline industry.
Max. one A4 page text!

Possible Solution:
The dichotomy of demand and supply describes the inherent inability to directly compare demand and supply in an individual origin-destination (O-D) market like Arlanda-Newark. The demand is generated at the level of an individual passengers O-D trip, while the airline provides the supply in form of flight leg departures on a network of scheduled flight operations. One flight leg provides joint supply of seats to many O-D markets simultaneously. That is, a flight leg Arlanda-Newark might be used by passengers traveling on various O-D trips, e.g., Arlanda-Newark, Arlanda-LAX, Kiruna-Newark, Kiruna-LAX, etc.. Thus, the total number of seats on a flight leg from Arlanda to Newark does not represent the supply of air transportation to the single O-D market Arlanda-Newark. As many airlines offer various airline paths/flight leg combinations (nonstop, one-stop, and connecting) that can be used to serve a specific O-D market, it is not practically possible to determine accurately the actual number of seats supplied to each O-D market, and, in particular, it is not practically possible to determine the number of seats supplied to the Arlanda-Newark market. On the other hand, the volume

of the Arlanda-Newark demand cannot be determined by simply counting the number of passengers on nonstop flights operating between the Arlanda and Newark. Detailed ticket samples of all passengers would be necessary to determine the complete demand.

Problem 8: Lufthansa and Air Berlin   **10 points**

The airline Air Berlin had to file for bankruptcy in August. Lufthansa wants to take over parts of Air Berlin to extend its subsidiary company Eurowings. With a fast take-over of the Air Berlin flights Lufthansa can avoid that slots are reallocated (currently, continous operation is financed via a public-sector loan from the German government). For all of Germany, Air Berlin (and their subsidiary Niki) holds about 12% of all slots, in Berlin Tegel the share is 45.6%, in Düsseldorf 28.1%. Figure 2 shows the distribution of "grandfathered" and newly-allocated slots at large German airports.
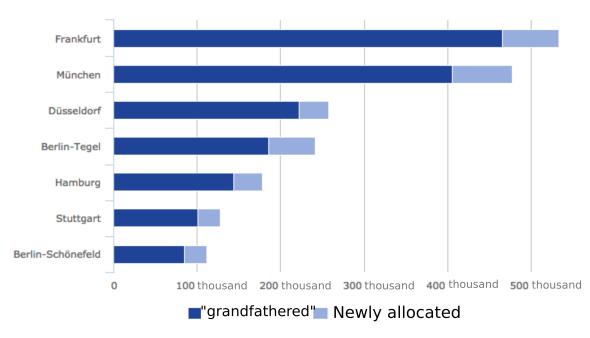

Figure 2: Allocated slots for arrivals and departures and German airports in the winter time table 2016/17 und summer time table 2017; "grandfathered" slots, that is, slots that are allocated to the same airline that did hold that slot before, are shown in dark blue, newly allocated slots in light blue. source: Flughafenkoordination der Bundesrepublik Deutschland.

Explain how slots are allocated at a level 3 airport, and then detail why a fast take-over of the Air Berlin flights would be beneficial for Eurowings/Lufthansa.

Possible solution:
Slot allocation at level 3 airport: First historic precedence = "grandfathered" slots (historic precedence applies to a series of slots that was operated at least 80% of the time during the period allocated in the previous equivalent season). Second slot pool: Once historic slots and changes to historic slots have been allocated, the coordinator will establish a slot pool, including any newly created slots. Slots available in the pool are allocated to airlines requesting a slot. 50% of the slots contained in the pool at initial slot allocation must be allocated to new entrants, unless requests by new entrants are less

than 50%. Within each category a request to extend an existing operation to operate on a year round basis should have priority over a new slot request.

With a fast take-over, Eurowings can claim historic precedence on the slots used by Air Berlin until now. Thus, those slots will not end up in the slot pool of the airports served by Air Berlin, which would mean that 50% of these slots are allocated to new entrants.

This is particularly interesting, as only few slots are newly allocated via the slot pool in large German airports. For example, in Berlin-Tegel, only about 50.000 of 240.000 slots were reallocated during the last year. But as Air Berlin holds 45.6% of the existing slots, this would directly give Eurowings 45.6% of these 240.000 slots, that is, about 110000 slots.

Good Luck!!!