Linköping University
Fall 2018
Communications and Transport Systems
Department of Science and Technology
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Exam
Air traffic and air transportation
TNFL01
TEN1
07.01.2019

- 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: Christiane Schmidt, tel 46 (0) 11 36 3212
- Hjälpmedel: Räknedosor som ej kan lagra text, alt. med tömda minnen är tillåtna. Ordböker engelsa-svenska är tillåtna. Inga andra hjälpmedel.
- Result will be published latest on January 21.

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 4 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: Overbooking **10 points**

Nordic Flights is a new small Swedish airline, its owners learned that they will have to use overbooking to be able to operate profitable.

(a) The owners are still unsure about the overbooking, give arguments why they need to use it.

(b) Explain what they will have to do using the following example. The physical capacity of the flight is 120 seats, the no-show rate is 20%, the standard deviation of the no-show rate is 9%. Compute the authorized capacity using the deterministic model and the probabilistic or risk-based overbooking model with an airline-specific goal of keeping DB = 0 with 95% confidence, and for the airline-specific goal of keeping DB = 0 with 90% confidence.

(c) Discuss why the models used in (b) do not reflect the complete reality, that is, discuss their limitations.

You may use the following formulas from the course:
Deterministic model: $AU = \frac{CAP}{1-NSR}$.
Probabilistic or risk-based overbooking model: for a one-tailed 95% confidence level under the assumption of a normal distribution of no-show rates $AU = \frac{CAP}{1-NSR+1.645STD}$.
Probabilistic or risk-based overbooking model: for a one-tailed 99% confidence level under the assumption of a normal distribution of no-show rates $AU = \frac{CAP}{1-NSR+1.28STD}$.

Max. one A4 page text!

Possible Solution:

(a) Unpredictable no-show behavior of passengers results in revenue losses (more tickets could have been sold), and the usage of overbooking is an attempt from revenue management (RM) to reduce these losses. As airlines operate on a very small profit margin, integrating overbooking in RM is essential to operate profitable. Optimal overbooking is part of optimizing the total expected flight revenues. Hence, airlines accept reservations in excess of aircraft capacity.

(b) AU is the Authorized Capacity: The maximum number of bookings that the airline is willing to accept, given a physical capacity of CAP (here $CAP = 120$). With the deterministic model $AU = \frac{120}{1-0.2} = 150$, that is, because the deterministic model assumes that the flight books up to the point where BKD = AU, 150 tickets will be sold. For the probabilistic or risk-based overbooking model with an airline-specific goal of keeping DB = 0 with 95% confidence we can use the second formula given, the factor of 1.645 accounts for the confidence level of 95%. Hence, we have $AU = \frac{120}{1-0.2+1.645\times0.09} = 126,57$, that is, Nordic Flights should be willing to accept a maximum of 126 bookings. For the probabilistic or risk-based overbooking model with an airline-specific goal of keeping DB = 0 with 90% confidence we can use the third formula given, the factor of 1.28 accounts for the confidence level of 90%. Hence, we have $AU = \frac{120}{1-0.2+1.28\times0.09} = 133,8$, that is, Nordic Flights should be willing to accept a maximum of 133 bookings.

(c) For the deterministic model, the assumption is that the no-show rate is deterministic, that is not realistic: the airline has no way to know during booking how many of the booked passengers will be no-shows. In reality, the no-show rate is uncertain, and, hence, has a non-zero STD. The deterministic overbooking model leads to a 50% probability of denied boardings (DB) should the flight book to AU. However, it also leads to a 50% probability of having spoiled seats. The deterministic model provides an acceptable overbooking answer if the airline is indifferent (economically or otherwise) between denied boardings and spoiled seats.

The probabilistic or risk-based overbooking model takes the uncertainty of the no-show rate into account. It represent the no-show forecast as a normal (Gaussian) probability distribution. Using the normal distribution, the airline has to specify a confidence level for DB (in case the flight is booked up to AU). The second formula reflects the AU for a future flight departure given the CAP and estimates of NSR and STD with an airline-specified objective of keeping DB = 0 with 95%, the third formula reflects the same value for an airline-specified objective of keeping DB = 0 with 90% confidence. Various factors can be incorporated in this model, however, if we aim to not only incorporate the uncertainty of future flight no-show behavior but also explicitly account for the costs associated with denied boardings and spoilage, this model reaches its limitations.

Problem 2: Dichotomy of Supply and Demand **10 points**

You are working for a large, international airline. In conversation with a representative of your favorite publisher at a conference, said representative asks you to quantify demand and supply on the route Arlanda-Brisbane. He is surprised to hear that you cannot easily quantify the demand and supply, as he easily can for, for example, his newest bestseller in November in Sweden. Give your conversation partner a detailed explanation on dichotomy of demand and supply in the airline industry, and connect to what distinguishes the airline industry from the publishing 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-Brisbane. The demand is generated at the level of an individual passenger's 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-Brisbane might be used by passengers traveling on various O-D trips, e.g., Arlanda-Brisbane, Arlanda-Sydney, Kiruna-Brisbane, etc.. Thus, the total number of seats on a flight leg from Arlanda to Brisbane does not represent the "supply" of air transportation to the single O-D market Arlanda-Brisbane. 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-Brisbane market. On the other hand, the volume of the Arlanda-Brisbane demand cannot be determined by simply counting the number of passengers on nonstop flights operating between the Arlanda and Brisbane. Detailed ticket samples of all passengers would be necessary to determine the complete demand.
In contrast, for the publisher, both supply and demand are generated at the level of books, hence, for him this dichotomoy does not exist.

Problem 3: CDM **10 points**

At an airport without CDM the ground handler and aircraft operator know when an aircraft is ready for departure, but the airport and ATC do not have this information.

Detail what this results in for the departure process.

Discuss what an introduction of CDM would change and enable.
Max. one A4 page text!

Possible Solution:
The ground handler and the aircraft operator know when the aircraft will be ready for departure, and, hence, when it will be ready for push back. ATC and the airport do not have this information. Hence, their planning is not based on the actual available information. For the airport this, in particular, relates to the availability of gates: the airport has no information on the actual time the gate will become avialable, thus, the gate allocation might be based on wrong information. ATC also has no information on when the aircraft is ready to leave the gate and ready to depart. Hence, they cannot plan the departure sequence (and taxi queue) according to the actual time, but to the old time communicated by the aircraft operator.
In case of an implemented airport CDM, the aircraft readiness time would be predicted and shared. Hence, ATC is able to plan the departure sequence earlier, and the runway and taxiway congestion can be managed better, that is, long taxi queues can be avoided, as the actual push back can be adapted to the current traffic situation, instead of the airlines performing push back in FCFS-manner. Hence, ATC holds aircraft at the stand instead of on the taxiway, which leads to fuel-savings for the airlines. In addition, the pilot will know the engine start-up time in advance. Moreover, the airport has a complete picture of which aircraft occupies which gate at what time, and can, thus, optimize the gate allocation.

Problem 4: Change of plans **10 points**

FlyNow has a fleet of two J31 (capacity 18 pax) and four F50 (capacity 50 pax). At 16:00 a routine control detects that one of the F50, which is currently located at airport B is damaged by hail. This can be fixed, but it is expected to take 12 hours. Figure **??** shows a screenshot of the system used for the daily planning and surveillance of flights and aircraft at FlyNow.
The flight controller at FlyNow has a suggestion for the current situation: swap the flight B-D and the later flight D-C that F501 should have served and let F502 operate them, which results in about 6.5 hours delay for the flight B-D. Then, F501 will operate F502's flight B-C.
Discuss how this suggestions influences the crew planning, maintenance planning and passenger planning. Make sure that you do not focus on just a single area, but give a broad picture of the possible consequences!
Max. one A4 page text!

Possible Solution:
Crew planning: We can assume that the crew who should have flown on the F501 is able to operate the F502. They will have to handle a delayed departure. Plus, they probably will have left for home and night rest at about 10:30 pm, which will now be about 5 am. That might influence their possibilites to continue their planned scheme after the night rest—they will have to delay the end of their night rest by 6.5 hours. If they would have worked over the night anyway and would have operated the flight

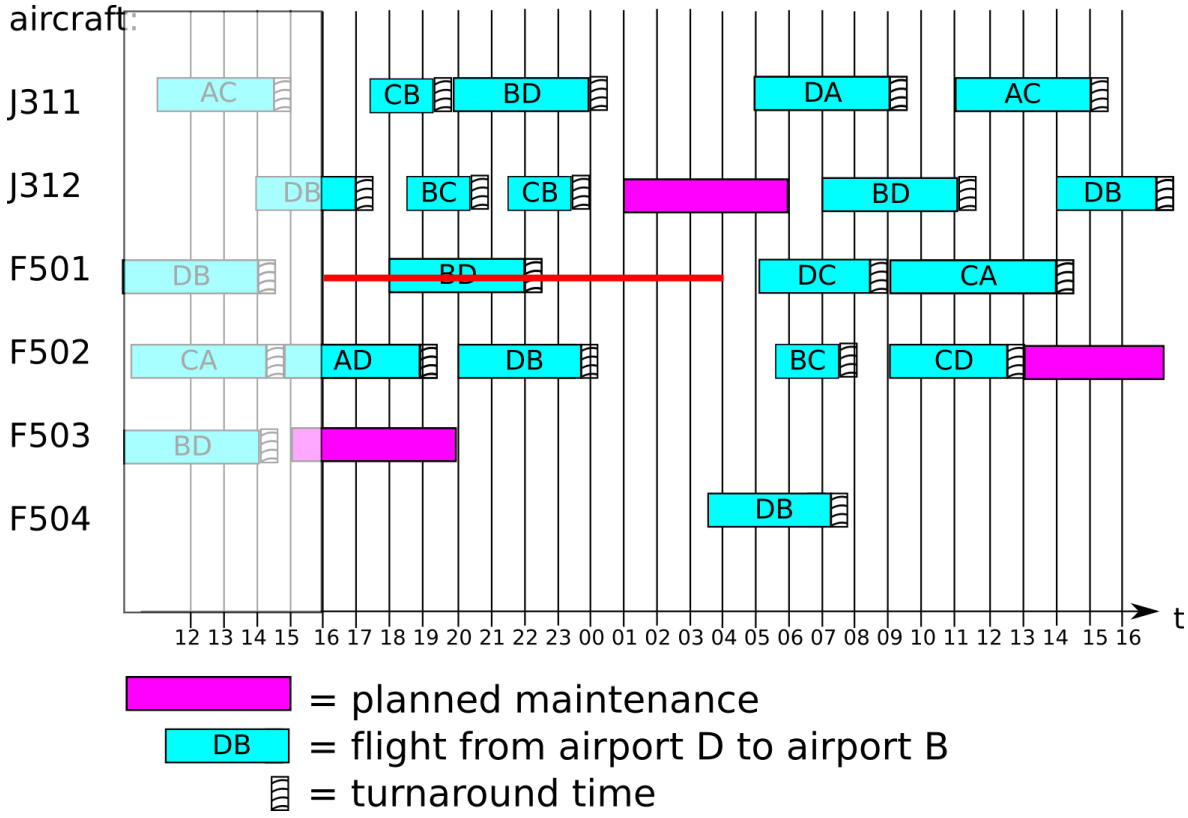

Figure 1: Screenshot of planning at 16:00.

D-C with the F501, the change should not influence them a lot. The crew who should have flown the B-C flight with the F502 and will now operate it with the fixed F501 shouldn't be influenced at all. **Maintenance planning:** The F502 will increase the flight time by about 5.5 hours—in comparison to the planned scheme. That might result in the need for maintenance earlier than planned originally. In the worst case, it might not be able to serve the additional flights at all. The next maintenance was scheduled after about 12 more flight hours, so, adding 5.5 flight hours might result in a violation of a rule for the max allowed flight hours inbetween maintenance. For the F501: the flight hours will be decreased by the schedule change, so, it won't violate any maintenance rules. Moreover, maybe it is possible to perform a service check during the reparation, which might postpone the next necessary maintenance. **Passenger planning:** The only passengers that will be influenced by the change are those that are booked on the flight B-D that should have been operated by the damaged F501 (original flight time 18:00-22:00). But the delay will probably be perceived as very inconvenient, as they will now land at 4:30 in the morning. The airline must check that the airport is open at that hour. The new arrival time might result in transport problems (leaving the airport) for the passengers etc. Possibly, the airline can help with ground transport, hotel or the like to reduce the bad-will.

Problem 5: 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, Mrs. A, has heard representatives of other airlines talking about yield, and now suggests to maximize the yield. Explain to Mrs. 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 1800 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 passengers 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 6: Crew planning **10 points**

The small airline FlyNow has the following timetable:

Flightnr	Dep time	Arr time	Dep AP	Arr AP
1	450	900	ARL	LLA
2	1000	1230	ARL	GOT
3	1020	1410	ARL	LLA
4	1810	2200	ARL	LLA
5	510	840	LLA	GOT
6	1030	13:55	LLA	UME
7	1510	1810	LLA	GOT
8	2020	22:20	LLA	ARL
9	615	800	UME	ARL
10	1545	1740	UME	ARL
11	1745	1930	UME	LLA
12	2000	2310	UME	GOT
13	430	09:10	GOT	ARL
14	920	1250	GOT	UME
15	1330	1640	GOT	UME
16	1920	2250	GOT	UME

Figure 2: Timetable.

The timetable is cyclic, with a cycle time of one day. This means that each flight in the table should be flown once each day (including weekends).
For each flight two pilots are needed. FlyNow managed to negotiate few, simple rules for the rest periods of their pilots:

- Maximum 10 flight hours per day.

- 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.

Moreover, all nights that are not spent at the home base incur additional cost for FlyNow. Deadhead flights are allowed, but should be avoided as they cost extra as well.
Use the above timetable and rules to explain how the crew planning problem for FlyNow's pilots can be solved. You do not have to do the complete planning (and cannot do so, as you do not have all information). Describe the different steps usually applied in crew planning, and use the timetable and rules to come up with examples for what you describe. Which objectives will FlyNow try to achieve?

Max. one A4 page text!

Possible Solution:
Crew planning is often solved in several steps. Usually the first step in crew planning is to construct so called "duty periods", which represent working days, and can be combined for so called "pairings" of several days. Each duty must fulfill all the rules for rest periods, and the same holds for each pairing. A pairing always starts and ends at the home base.
If we assume that all pilots can fly on all flights (because we have only a single aircraft type) possible duties are:

- 1, 6 (flight time of 7:35, which is less than 10 hours)
- 2, 15 (flight time of 5:40)
- 9, 3, 8 (flight time of 7:35)

Duties can then be combined for pairings. If we assume that Arlanda is the home base, a pairing could be: ARN, 1, 6, rest of 16h20mins, 9, 3, 8, ARN
Each pairing causes cost, the cost depends on the number of night stays not at the home base, deadhead flights, etc. FlyNow will be interested to minimize the cost, that is, to find the pairings that minimize the total cost for the airline, such that a pilot is assigned to each flight.
Once pairings are chosen, these need to be combined to a monthly working schedule, which is then assigned to a specific crew member. This can be done with different methods, examples are rostering and bidline.

Problem 7: Low Cost Carriers — 10 points

A new manager, Z, starts at the low cost carrier FlyNow, he wonders how FlyNow is able to offer tickets that are more than 50% cheaper than those of competing full service carriers. Explain to Z what factors result in these ticket prices. Make sure to give a broad picture and do not concentrate just on a few factors.

Max. one A4 page text!
Possible Solution:

FlyNow has reduced cost in various sectors when compared to a full service carrier, this includes, for example:

- Higher Aircraft Utilisation: A/c are used for more flight hours per day.
- No In-Flight Catering/Sales on Board: all food and drinks must be bought.
- No Agent Commission: tickets are sold via the internet, direct contact to customer, no agents.
- Cheaper Airports/Landing Fees: FlyNow flies from smaller airports, not located direct in metropolitan areas.
- Seat Density: more seats are used on the same a/c type.
- One a/c type: crew and maintenance don't need to be qualified for several types.
- Lower Crew Cost and longer working hours.
- High Cabin Factor: different prices to reach high cabin factor in the end.

Because of reduced cost, it can offer cheaper tickets.

Problem 8: Monarch Airlines and Gatwick Airport — 10 points

Monarch Airlines, also known as Monarch, was a British charter airline. It was created in 1967 by the owners of Cosmos, a travel agency, specifically to cater to the new and rapidly expanding package-holiday market. Monarch's first charter flight took off the following year from Luton airport, where the company was headquartered, for Spain. And that was the story for the next three very successful decades: flying sun-seeking Britons to Mediterranean resorts for cheap, all-inclusive holidays. However, that business model came under severe strain in the early 2000s with the arrival of the internet. Customers could now choose and book their own holidays much more easily. And the rise of low-cost airlines such as easyJet, founded in 1995 and also based at Luton, gave travellers new alternatives to charter flights. Passenger numbers on non-scheduled (charter) flights operated by British airlines fell by two-thirds from 2001 to 2016, even as the overall number of flights increased dramatically. Low-cost airlines were the main beneficiaries.
As profits declined, Monarch took the decision to get out of the charter market and concentrate on short-haul flights. In 2004, the company became a low-cost airline, that is, a scheduled and no longer a charter airline. But the European market is fiercely competitive and increasingly dominated by just four big players: Ryanair, easyJet, the Lufthansa group and IAG (a group which includes British Airways, Aer Lingus and Iberia). Monarch airlines was not big enough and, thus, did not have the purchasing power, to survive in this market.
In October 2017, Monarch, Britain's fifth-biggest airline, had ceased trading and went bankrupt. It was the country's biggest airline ever to collapse.
The airline's headquarters were at Luton, and it had operating bases at Birmingham, Leeds/Bradford, Gatwick and Manchester.
In the end of November 2017, Monarch's administrators won their legal battle and were allowed to raise capital by selling Monarch's take-off and landing slots at London Gatwick and Luton, because "Monarch remains an 'air carrier' and is entitled to the slots it claimed".
British Airways' parent company, IAG, bought the take-off and landing slots previously belonging to Monarch Airlines at Gatwick airport. Gatwick is the busiest single-runway airport in the world, From the start of the summer schedules in late March 2018, IAG had just over one-fifth of the slots. The biggest carrier at the Sussex airport remains easyJet, with over 40 per cent of slots. It had expressed

interested in the Monarch slots, as had Norwegian and Wizz Air.

Explain how slots are allocated at a level 3 airport, and then detail why IAG invested at least 50 million pounds in these slots instead of receiving slots at the next SC at no cost?
Max. one A4 page text!

Possible solution:
Slot allocation at level 3 airport: First historic precedence = "grandfathered" slots (historic precedence applies to a series of slots (at least five slots at about the same time of a specific week day) 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 investing 50 million pounds for these slots, IAG was able to get all of Monarch's slots at Gatwick airport. If they would not have bought the slots, they either would have all gone to another buyer– because easyJet, Norwegian and Wizz Air all expressed interest in these slots–or they would have landed in the slot pool for allocation at the next SC. This would have given IAG a (relatively small) percentage of the slots, as 50% of these slots would have been allocated to new entrants, and the remaining slots would be split among several airlines. Hence, buying the slots enabled IAG to directly increase the number of slots significantly, and, hence, to be able to operate a significantly larger number of flights out of Gatwick.

Good Luck!!!