Linköping University
Fall 2019
Communications and Transport Systems
Department of Science and Technology
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Exam
Air traffic and air transportation
TNFL01
TEN1
21.10.2019

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

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: From Flight Schedule to Routing — 10 points

Your colleague missed the lectures on how an airline with a given (i.e., already computed) flight schedule for a season assigns aircraft to all flights for each day in the schedule. Explain to him/her in detail what makes this a complicated problem, and how it is handled in practice. What are the substeps taken to solve this? What are the requirements for a solution?
Max. one A4 page text!

Possible Solution:
Due to the number of flights in the schedule and the number of available aircraft, assigning aircraft to all flights for each day of the season is a large problem, and, for larger airlines, it can not be solved as is.
Thus, the problem is decomposed: Usually, this is done by aircraft type. First, the complete fleet of the airline is split into subfleets of interchangeable aircraft. Then, the so called **fleet assignment** problem is solved: for given flight schedule and fleet sizes, a fleeting is computed, that is, all flights are assigned to a subfleet, without determining which aircraft should serve which flight. For a solution of the fleet assignment problem we can aim for maximizing the number of passengers, for minimizing the costs, or for obtaining a robust solution. Several requirements must be fulfilled by any such solution: We need to obey airport limitation on aircraft type, crew and maintenance limitation on the aircaft type, and need to balance the use of all aircraft.
After that step, we are still left with a routing problem, that is, we still need to assign aircraft to flights, but both the number of aircraft and the number of flights is now significantly reduced in each subproblem (for each subfleet). As the second step, the so called **aircraft routing** problem is solved, which assigns a route to each aircraft. Here, we are given a one-fleet schedule, the matching subfleet, maintenance constraints, and other operational conditions, and we want to compute a route for each aircraft. That is, after this step an aircraft has been assigned to each flight of the season in the airline's schedule. With a solution of the aircraft routing problem we aim for a feasible assignment that is robust, that is, small perturbations do not have effects for a long time or in large parts of the airline's network.

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 example, for 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: 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 description 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 5: Freedoms of the Air — 10 points

In the 1944 Chicago Convention five (or by extension nine) freedoms of the air were defined. What are these freedoms of the air, what do they enable or enforce whom to do? Some of these freedoms have lost importance since 1944, name one such freedom and explain why it has lost importance. Others are still the core of any internationally operating airline, name at least one such freedom and explain what they allow the airline to do.
Max. one A4 page text!

Possible solution:
The nine freedoms of the air are a set of commercial aviation rights granting a country's airlines the privilege to enter and land in another country's airspace, formulated as a result of disagreements over the extent of aviation liberalisation in the Convention on International Civil Aviation of 1944, known as the Chicago Convention. They are usually granted to airlines from two countries by bilateral agreements between the two states.
The second freedom of the air, the right to refuel or carry out maintenance in a foreign country without embarking or disembarking passengers or cargo, has lost importance since 1944. At that time, aircraft needed refueling stops to cover large distances. Given today's aircraft range, refueling stops are virtually unneeded, hence, the second freedom of the air is no longer vitally important for an airline's operation.
The fifth freedom of the air, the right to fly between two foreign countries on a flight originating or ending in one's own country, is still an important right–Swedish (or better Scandinavian) delegations still aim for it in any bilateral agreement with other countries. This right, for example, enable Singapore airlines to continue to JFK on their flight from Singapore to FRA.

Problem 6: 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.

Problem 7: Crew rest time **10 points**

Pilot X works for airline FlyEurope. Because of good contacts to the unions, FlyEurope 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: $\min\{$(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 May 4, May 5-7 he had time off at his home base FRA, on May 8 he flew 5 flight hours, with the last flight ending at 14:00 UTC.
On May 9 he flew:

- FRA-LIS, 3h 05 min flight time, 07:00-10:05 UTC
- LIS-FRA, 3h 00 min flight time, 10:45-13:45 UTC
- FRA-OSL, 2h 00 min flight time, 14:30-16:30 UTC
- OSL-FRA, 2h 05 min flight time, 17:15-19:20 UTC

Unfortunately, FlyEurope's pilot Y is sick on May 9. Amongst others he was scheduled to fly flight FE123, FRA-CPH, 1h 20 min flight time, 20:20-21:40 UTC. The crew controller plans that pilot X takes over flight FE123.

(a) According to the rules for rest periods: Is it possible that pilot X flies on flight FE123, is it a feasible pairing? If yes, what is the earliest time a flight he is scheduled for can depart on May 10?

(b) If X is used on flight FE123, what other consequences result for crew planning?

Max. one A4 page text!

(a) According to the rules for rest periods: Is it possible that pilot X flies on flight FE123, is it a feasible pairing? If yes, what is the earliest time a flight he is scheduled for can depart on May 10?

Possible solution. The last two rules aren't influenced by the additional flight. The originally scheduled flights for X have a total of 10h 10 min flight time. According to the first rule this can be exceeded by max 2 hours. 1h 20min = 80 min, 10 min + 80 min =90 min $<$ 2h, thus, it is possible to schedule X for flight FE123. In the night May 8 - May 9, X had 17 h rest, this exceeds 16h by one hour, according to the formula $\min\{1/3, 1\}h = 1/3$h = 20 min can be assigned to that night. This leaves 1 hour 10 min to be charged to the night May 9 - May 10, and it needs to be charged with twice its value: 2hours 20 mins. Thus, X must have 18h 20 mins of rest. Consequently, the first flight on May 10 for X could start at 16:00 UTC.

(b) If X is used on flight FE123, what other consequences result for crew planning?

Possible solution. X arrives at CPH, which is not his home base, a hotel night needs to be added. Moreover, X will not be at FRA on May 10, 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 CPH. Moreover, instead of at 19:20 UTC + 16h = 11:20 UTC, he can now only start his next duty at 15:40 UTC. Possibly other pilots will receive a new duty to take over X's original flights from May 10, this may have further consequences for the crew planning for the following days.

Problem 8: 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.

Good Luck!!!