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
07.01.2020

- 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. Usually, you should give a broad picture and not a narrow answer taking up only a single aspect.
- 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 the Cabin Factor **10 points**

You get hired by a new airline, AirNordic, to make sure that they operate with a profit. The owner of AirNordic, Mrs. Cidron, has heard representatives of other airlines talking about cabin/load factor, and—thinking that AirNordic should try to serve as many passengers as possible to operate profitable—she now suggests to you to maximize the cabin factor. Explain to Mrs. Cidron what the cabin or load factor is, and detail why it is not a good idea to solely aim for maximizing the cabin factor.
Max. one A4 page text!

Possible solution:
The cabin or load factor gives the ratio of airline output (seats) that is sold. It can be defined for a single flight leg, for several flight legs, or for the complete airline over a specific time period. For a single flight leg the load factor is defined as the number of passengers divided by the number of seats on the flight. For more than one flight two definitions exist: the average leg load factor (ALLF) and the average network of system load factor (ALF). The ALLF is the average of the load factors of the single flights, while the ALF is the ratio of total RPK to ASK, where ASK denotes the available seat kilometers, that is, the number of availabe seats flown for one kilometer and RPK denotes the revenue passenger kilometers, that is, the number of kilometers over which a paying passenger was transported. Hence, in general, these two values differ: for the ALLF flights of different lengths are valued equally (e.g., a 300 km flight with load factor 90% is weighted equally as a 3000 km flight with load factor 65% (which results in a ALLF of 77.5% for these two flights)), while the ALF is an average per km. Both measures are correct, but are used in different ways. The ALLF is used, e.g., for the analysis of passenger service levels on a series of flight leg departures (e.g., all flights from Arlanda to Heathrow in October), the ALF is more common and used in most financial and traffic reports of the system-wide airline.
As your job description states, you should help to operate AirNordic profitable, and, as any other airline, AirNordic 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 the unit cost is the ratio of total operating expense and ASK, and the yield is a nominal unit income (the income per pax-kilometer).
If AirNordic decides to maximize the cabin factor, this might be obtained by selling extremely cheap tickets. Hence, many or all passengers could pay a very low fare. This would result in a low yield, and, in particular, it could lead to the total revenues not covering all operating expenses. In this scenario, Air Nordic would have a high load factor, but it would not operate with profit, or at the least it would not maximize the profit. Thus, such a one-sided strategy should not be followed by AirNordic. The airline should maximize its profit not the number of customers served.

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: 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

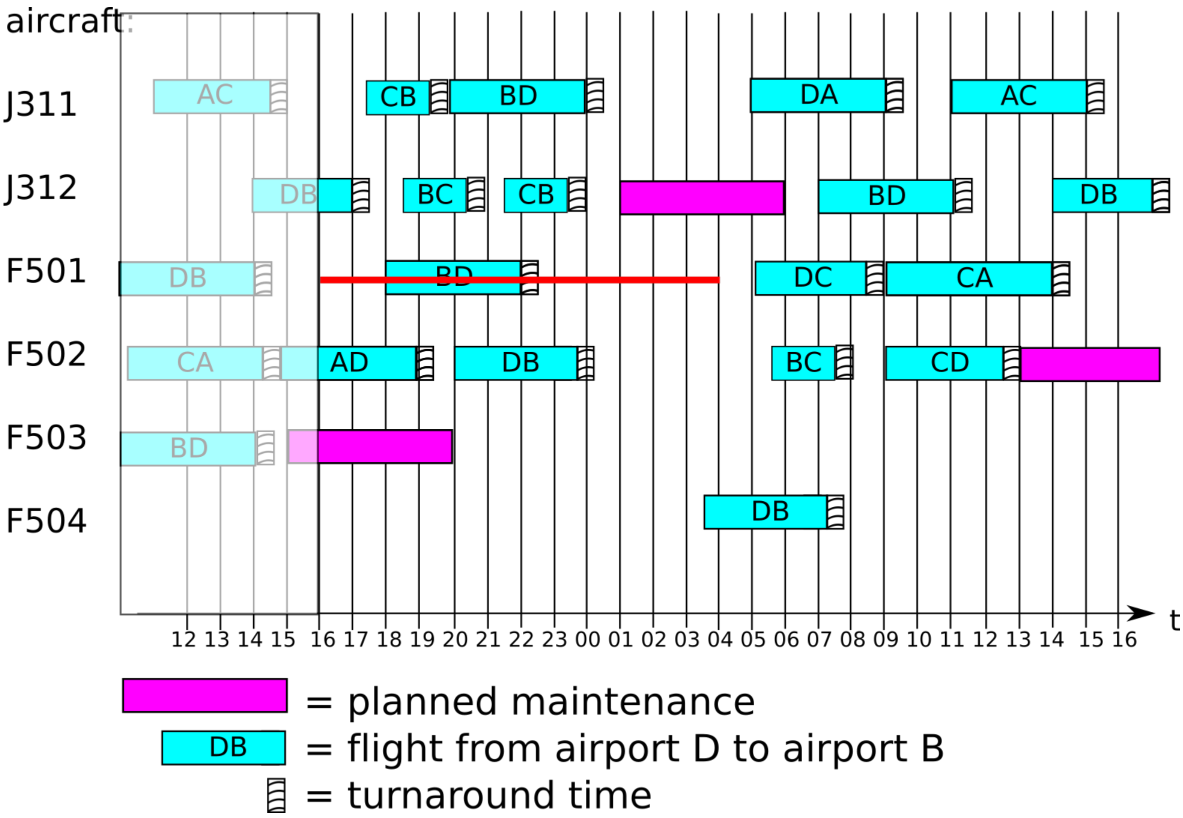

Figure 1: Screenshot of planning at 16:00.

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 1 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 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 8: Elasticity of Demand and Differential Pricing — 10 points

In Figure 2 two (simple) price-demand curves are given.

(a) Explain what price elasticity of demand is. Which of the two curves represents a more price-elastic demand?

(b) Explain differential pricing and its advantages using Figure 2(b).

Max. one A4 page text!

Possible Solution:

(a) Price elasticity of demand is the percent change in total market demand that occurs with a 1% increase in average price charged. In the curve in Figure 2(a), the increase from price P_1 to P_2 leads only to a small decrease in demand, in the curve in Figure 2(b), the increase from price P_1 to P_2 leads to a larger decrease in demand. Hence, the demand of (b) is more price-elastic.

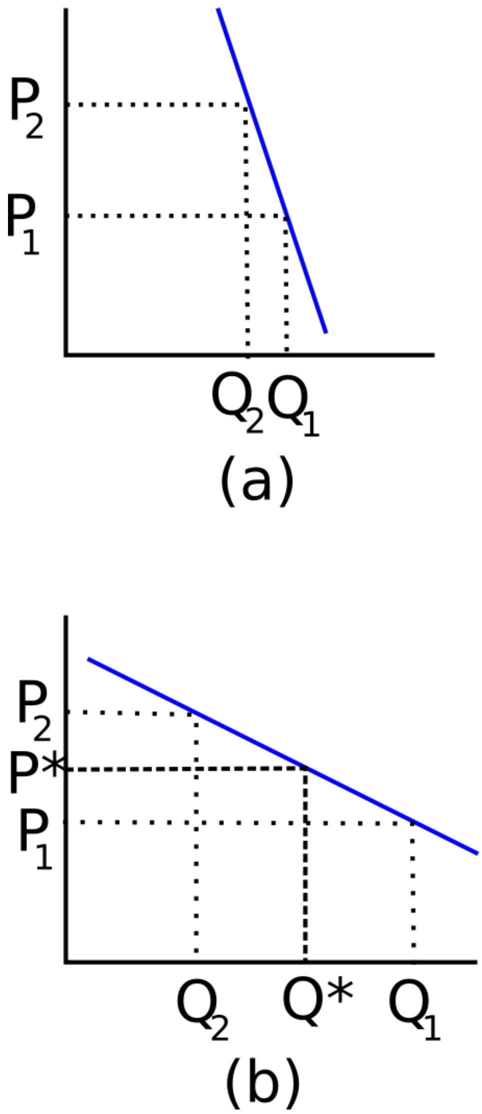

Figure 2: Two price-demand curves.

(b) The maximal possible revenue is the area under the triangle build by the two axes and the (extended) price-demand curve. However, for the airline to achieve this, it would need to charge a different price for each passenger based on his or her WTP. The airline could just use a single price $P*$, or, using differential pricing, could decide to sell at two prices P_1 and P_2. We argue why the latter is beneficial for all actors:

- Customers:
  - $(Q_2 - Q*)$ passengers paying P_2 would not fly at $P*$
  - $(Q * -Q_1)$ passengers who might have been willing to pay $P*$ benefit as well
  - High-fare passengers paying P_1 pay more than they would with single price level $P*$, but they pay less and/or enjoy more frequency of flights given the low-fare passengers' presence.
- Airlines: Offering two different fares, instead of a single fare of $P*$ for all passengers

increases total revenues with little impact on total operating costs. (At $P*$: rectangle spanning $P*$ and $Q*$, at P_1 and P_2 the sum of the two rectangles represent the total revenues of the airline.) With only a single fare many legacy airlines with high costs would be unable to attract enough passengers (and revenue) to cover total operating costs.

Good Luck!!!