

**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**  
**22-10-2018**

- 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
- Examiner: 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. Ordböcker engelska-svenska är tillåtna. Inga andra hjälpmedel.
- Result will be published latest on November 5.

**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: 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 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-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 dichotomy does not exist.

**Problem 2: 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 available, 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 3: Safety Management Systems**

**10 points**

Nordic Flights is a new small Swedish airline that will offer domestic flights. Before they are allowed to start they have to establish a safety management system. Explain what such a safety management system encompasses and present the airline a draft of a safety management system that they could implement directly. Do not forget that they do not know anything about Safety Management Systems, hence, make sure you give them a step by step guide.

*Max. one A4 page text!*

Possible solution.

A safety management system (SMS) is a systematic approach to managing safety, including the necessary organisational structures, accountabilities, policies and procedures. For Nordic Flights this could include:

1. They describe which security risks they need to manage (e.g., human error because of fatigue or incompetence, pilots not following company guidelines, maintenance crew working negligent, etc.) and how the company should handle them. They may also establish security related goals, for example that the number of incidents should not be higher than a certain threshold.
2. Then the company has to work according to the first point.
3. The work must be documented carefully.
4. Relevant measures should be used to see whether the goals according to point 1 have been reached. The number of incidents per year could be such a measure.
5. If the goals could not be reached, for example, if the number of incidents exceeds the threshold, they have to identify the reasons, find counteractions, change the procedures, and update the SMS if necessary.

### **Problem 4: Refueling**

**10 points**

Refueling at Littletown lies within the responsibility 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 volume 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 0,6kg/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

*Max. one A4 page text!*

Possible Solution.

The larger truck has a capacity of 15000l, the smaller of 10000l. The density is 0.6kg/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.

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 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

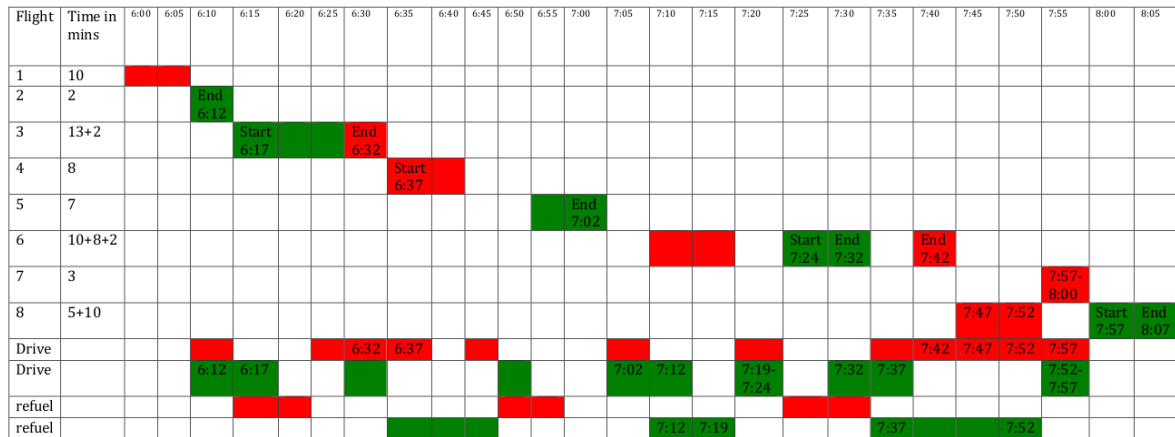


Figure 1: The gantt chart shows when which truck serves which flight. In some cases both trucks are needed for a single aircraft. Black times indicate start and end times.

ticket. The passenger revenue for this flight leg is  $65 \cdot 1800 = 117\,000$ ; the revenue passenger kilometer (RPK), that is, the number of paying passengers transported for one kilometer, is  $65 \cdot 1000 = 65\,000$ . The yield is then defined as the ratio of passenger revenue and RPK, thus, for our example, the yield is  $117\,000 / 65\,000 = 1.8$ .

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  $\text{Operating profit} = \text{RPK} \cdot \text{yield} - \text{ASK} \cdot \text{unit cost}$  (income minus cost), where ASK denotes the available seat kilometers, that is, the number of available 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: 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 interest 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: 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 fleet assignment 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 aircraft 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 8: Nine freedoms of the air**

**10 points**

FlyNow, a small Swedish airline, has new employees, and it is your job to explain the nine freedoms of the air to them. Give a general definition, and name at least three freedoms and what they could enable FlyNow 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.

One freedom grants an airline to fly from one's own country to another. FlyNow could operate the route Arlanda-London, arriving in the UK.

Another freedom grants an airline the right to fly over a foreign country without landing. FlyNow could for example operate the route Arlanda-London, overflying Denmark without landing in Denmark.

Another freedom grants an airline the right to fly inside a foreign country without continuing to one's own country. FlyNow could operate a flight Paris-Marseille, without offering any flight from Marseille to Sweden.

**Good Luck!!!**