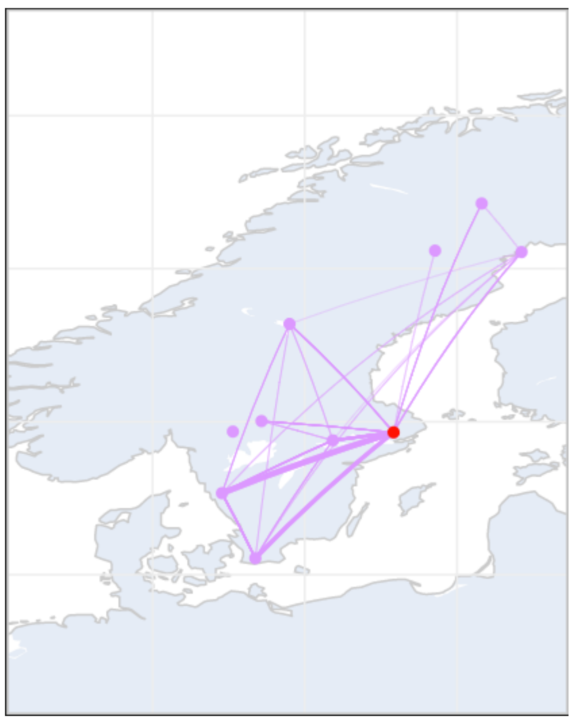
ASSIGNMENT PART 2

AE4423 – Airline Planning & Optimisation



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Introduction

Your airline is considering the option of developing a regional network to feed the international network that you developed in Part 1 of the assignment. Apart from your main hub, there are 11 other Italian destinations available to operate flights to. In this Part 2, Problem 3, you will have to design the flight schedule and the aircraft routings for your operations, in order to maximize the profits.

In particular, the files *Group_X_Regional_Airport_info.csv, Group_X_Regional_Demand.csv,Group_X_Hourly_Coefficients.csv,Group_X_Regional_Distances.csv,Aircraft_fleet_info.xlsx [*]* contain data on the airports from which you have the right to operate, the daily demand for regional Origin-Destination pairs in Italy, the coefficients of this demand for every hour per day, the distances between the airports in your network, and the aircraft data respectively.

Your hub airport is the same airport as in Part 1 of the assignment (included as the first airport in *Group_X_Regional_Airport_info.csv*)

First read the entire assignment carefully (including the appendices) to extract all information required to adapt the models presented in the lectures!

[*] – X is a place holder for your group number.

Problem 3. Flight scheduling and aircraft routing problem

Your goal in this problem is to define the flight schedule for a standard day, the aircraft routing for that flight schedule and the fleet that will give you the highest profit.

Given its environmental goals, the airline is considering the option of operating a mix of kerosene and electric aircraft. With the input data available in the Excel file supplied with the assignment and the Appendix, determine the flight schedule and aircraft routing for one day (24-hour period). That is, you have to determine which aircraft to fly a specific route as well as the departure time of each flight. Assume that all your aircraft have to start and end the day at your hub airport and that only flights to and from the hub are considered (i.e., no spoke to spoke flights).

The objective is to maximize the profit within one day.

To achieve this goal, you need to:

1. Setup a computer model (e.g., in Python or Matlab) according to the dynamic programming framework presented during the lectures.
   Note: in this problem you will not use any commercial solver.
2. Write in your assignment the pseudo-code of your computer model.
3. Determine the optimal solution, assuming the data in the attached Excel files and the Appendix from this assignment.
4. Report the fleet that you use; the frequency of flights per day between you hub airport and spokes; the schedule between your hub and the first regional airport included in the Group_X_Regional_Airport.csv with indication of which aircraft is flying each flight and the load-factor; and all KPIs that you find relevant to describe your flight network.

General information

- **Motivate your choices, comment on results, and be critical towards results!**
- Describe the mathematical model, your assumptions, results and KPIs for each of the assignments in detail in a comprehensive report of **no more than 10 pages A4** (excluding cover but including appendixes; font equivalent to Times New Roman – 12 pt., line spacing 1.15 and standard margins). **Note that the report shall not contain any computer code.**
- Use **figures** and **tables** to present your results and KPIs and support your conclusions.
- Submit your report and model script file(s) through **BrightSpace** (assignment folder in our course webpage) at the **latest on Friday 19th of January, at 18.00 hrs**. Do not forget to include the group number, names, and student IDs in the report (and script file(s)). Do **NOT** submit input (Excel) files. Files submitted by email will not be considered.
- **If you fail to meet the deadline**, 0.5 points will be deducted from your grade for **each day** after the deadline. No excuses will be accepted! Make sure that you work as a group and save the latest versions of your work in multiple places.
- All files uploaded in BrightSpace should be uploaded as **individual files** (i.e., do not compressed as '.zip', '.tar', …) to be subjected to **Turnitin check**. **If compressed files are uploaded**, 1.0 points will be deducted from your grade.
- **If you fail to obtain a grade of 5.5 or higher you will fail the assignment.** In that case, you will get a chance to improve your work and pass the assignment. Your final grade cannot become higher than 6.0 in that case.
- You should include a separate overview of the **workload distribution** of each group member. Indicate (in percentages) each member's contribution to the three categories **mathematical modelling (30%)**, **programming (50%)** and **reporting (20%)**. Based on this overview you will receive an individualized grade for the assignment. There is a maximum different of 2 points possible between group members. For an example of the format see Appendix F.
- **An assessment matrix** will be available to clarify the grading process.

Appendices

A. Revenue

Revenue is generated by transporting passengers. To determine the revenue, yield is expressed in € per Revenue-Passenger-Kilometer (RPK). The following revenue formula is to be used:

- The yield depends on the distance and can be formulated as follows:

$$Y_{EUR_{i,j}} = 5.9 \cdot d_{ij}^{-0.76} + 0.043$$

  where:
  - $Y_{EUR_{i,j}}$ is the yield in € between origin i and destination j.
  - d_{ij} is the distance in km between origin i and destination j.

B. Costs

Operating your aircraft logically induces costs. For this assignment, two types of cost need to be considered (all expressed in Euros):

- All aircraft are leased, and therefore a leasing cost needs to be accounted for. The weekly leasing cost is a fixed amount depending on the type of aircraft, and can be found in Appendix E, Table 1.
- Operating costs consist of four components:
  - Fixed operating costs (C_X^k) are costs **per flight leg** and represent costs such as landing rights, parking fees and fixed fuel cost. They depend only on the aircraft type k.
  - Time-based costs (C_T^k) are costs that are defined in € per flight hour and represent time-dependent operating costs such as cabin and flight crew. They depend on the distance of the flight leg and the aircraft type k. Time costs can be defined as follows:

$$C_{T_{ij}}^k = c_T^k \frac{d_{ij}}{V^k}$$

    where:
    - $C_{T_{ij}}^k$ is the total time cost for a flight leg between airports i and j, operated by aircraft type k.
    - c_T^k is the time cost parameter for aircraft type k.
    - V^k is the airspeed of aircraft type k.
  - Fuel costs ($C_{F_{ij}}^k$) for kerosene powered aircraft, which are dependent on the distance flown and can be expressed as follows:

$$C^k_{F_{ij}} = \frac{c^k_F \cdot f}{1.5} d_{ij}$$

where:

- $C^k_{F_{ij}}$ is the fuel cost for a flight leg between airports i and j, operated by aircraft type k.
- c^k_F is the fuel cost parameter for aircraft type k, expressed in gallon per kilometer.
- f is the fuel cost, equal to 1.42 USD/gallon in 2020. (Conversion to € already accounted for in the formula)

○ Energy costs ($C^k_{E_{ij}}$) for electric aircraft. This is dependent on the battery capacity of the aircraft, the distance flown and the range of the aircraft. It can be expressed as follows:

$$C^k_{E_{ij}} = e \cdot G^k \frac{d_{ij}}{R^k}$$

where:

- $C^k_{E_{ij}}$ is the energy costs to recharge the batteries for a flight between airports i and j, operated by aircraft type k
- e is the price of energy, assumed to be 0.07 €/kWh
- G^k is the energy in a fully recharged aircraft type k
- R^k is the range of aircraft type k.

The total operating cost for a flight leg between airports i and j, operated by aircraft type k can then be expressed as:

$$C^k_{ij} = C^k_X + C^k_{T_{ij}} + \left(C^k_{F_{ij}} + C^k_{E_{ij}}\right)$$

The required parameters to determine the operating costs can be found in Table 1.

It should be noted that for flights departing or arriving at your hub airport the operating costs can be assumed to be 30% lower due to economies of scale (this includes fixed operating costs, time-based costs, and fuel costs, but <u>not</u> the energy costs).

C. Aircraft routes to consider

Your airline will only consider to add aircraft routes that:

- Are profitable – i.e., you do not have to use all aircraft in your fleet;
- Have a minimum of 6 hours of block time per day to consider to add the aircraft to your flight schedule;
- Respect range and runway constraints.

D. Demand management

The demand per hour can be computed by multiplying the daily demand by the hour-coefficients given in the Excel files attached to this assignment. You should use the following formula:

$$Dem(t)_{i,j} = Dem_{i,j} \times Coef(t_i)$$

Where

- $Dem(t)_{i,j}$ is the demand for hour t in the route i,j
- $Dem_{i,j}$ is the daily demand between airports i and j
- $Coef(t_i)$ is the coefficient for hour t given in the new Excel file for airport i.

Note:

- the demand is given per route and they already consider the connection of passengers at the hub;
- demand for a given hour of the day will be available at any (departure) time within that hour.

When you fly at hour t, you can assume that you can capture the demand you estimated for hours t, $t-1$, $t+1$ and $t-2$, if available. Passengers from hour t have priority over passengers from time $t-1$, followed by passengers from $t+1$ and then $t-2$.

After adding an aircraft route to your solution, you should remove the demand you transported. To do this, remove demand from t, $t-1$, $t+1$ and $t-2$, sequential, until the aircraft is full or no more demand is available.

E. Aircraft data

You have the choice to operate any of the three aircraft defined in Table 1.

Table 1: Aircraft data

Aircraft type	**Aircraft 1:** Regional turboprop (kerosine)	**Aircraft 2:** Electric regional aircraft	**Aircraft 3:** Electric twinprop aircraft
Aircraft characteristics			
Speed [km/h]	550	480	350
Seats	45	48	20
Average TAT [mins]	25	25	20
Additional charging time[1] [mins]	--	45	20
Maximum range [km]	1,500	1,000	400
Runway required [m]	1,400	950	750
Cost			
Daily lease cost [€]	2,143	3,142	1,714
Fixed operating cost C_X [€]	300	120	90
Time cost parameter C_T [€/hr.]	750	750	750
Fuel cost parameter C_F[gallon/km]	1.0	--	--
Batteries energy G^k[kWh]	--	8216	2130
Available Fleet	5	3	3

[1]This time has to be added to the 'Average TAT' to obtain the necessary TAT of the aircraft.

F. Other considerations

Consider the following elements:

- Besides the flight time and the TAT, assume that:
    - the aircraft takes 15 min extra for take-off and get to cruise
    - position;
    - the aircraft takes 15 min extra for approaching the destination
    - airport and landing.
- Divide your scheduling horizon (24 hours) into time stages of 6 minutes. That is, each hour will be divided into 10-time stage, where, e.g., 5.4 = 5h24min.

Individual workload

To distinguish between each student's workload in the group, you are required to provide an indication of each group member's workload in three separate disciplines. Provide the workload distribution in a separate file uploaded along with the assignment and follow the template below (or similar).

Student names	Mathematical modelling (30%)	Programming (50%)	Reporting (20%)
Student name #1	# %	# %	# %
Student name #2	# %	# %	# %
Student name #3	# %	# %	# %