Regional network development, including electric aircraft

An Italian airline operates regional flights from its hub at Malpensa airport (LIMC). Apart from your main hub, they operate in 14 other Italian destinations.

This exercise aims to develop a network and fleet plan for this airline, considering the mix of kerosine and electric aircraft provided in Appendix C. Kerosine aircraft can be refuelled in any airport. Still, the batteries of the electric aircraft can only be charged at the hub airport.

The excel file provided together with this file contains the airport, distances, and demand data to consider.

Additional Information

- You can lease as many aircraft as you desire if this maximizes profit.
- Assume that the aircraft is only available for operations for **10 hours** per day, ensuring sufficient time for maintenance and no operations in periods of the day with very low demand.
- Turn-Around-Times (TAT), including landing and take-off times (LTO), **depending on the aircraft type** and route. Typical TATs per aircraft type can be found in Table 1.
- There are multiple commercial LP model solvers. The best known, Gurobi and ILOG CPLEX, are free for academics and have a limited trial version that you can use. MatLab also has its solver toolbox (linprog) and a few freeware software, like COIN-OR.

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Appendices

A. Revenue

Revenue is generated by transporting passengers. To determine the revenue for Problem 1, 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.

Assume that, in this case, the revenue generated by passengers connecting at the hub will be 10% lower to capture a lower willingness from passengers to transfer between flights. Also, consider that the average load factor is not higher than 80% of the cabin capacity in the long term.

B. Costs

Operating your aircraft logically induces costs. For Problem 1 of this assignment, two types of cost need to be considered (all expressed in Euros):

- All aircraft are leased, so a leasing cost must be accounted for. The weekly leasing cost is a fixed amount depending on the type of aircraft and can be found in Appendix D, 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 costs. They depend only on the aircraft type k.
  - Time-based costs (C_T^k) 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:

    $$C_{F_{ij}}^k = \frac{c_F^k \cdot f}{1.5} d_{ij}$$

    where:
    - $C_{F_{ij}}^k$ is the fuel cost for a flight leg between airports i and j, operated by aircraft type k.
    - c_F^k is the fuel cost parameter for aircraft type k, expressed in gallons per kilometre.
    - f is the fuel cost of 1.42 USD/gallon in 2020. (Conversion to € already accounted for in the formula)
  - Energy costs ($C_{E_{ij}}^k$) for electric aircraft. This depends on the aircraft's battery capacity, the distance flown and the range of the aircraft. It can be expressed as follows:

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

where:

- $C_{E_{ij}}^{k}$ is the energy cost 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:

$$C_{ij}^{k} = C_{X}^{k} + C_{T_{ij}}^{k} + \left(C_{F_{ij}}^{k} + C_{E_{ij}}^{k}\right)$$

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 data

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

Table 1: Aircraft data

Aircraft type	Aircraft 1: Regional tuboprop	Aircraft 2: Regional jet	Aircraft 3: Single aisle twin engine jet	Aircraft 4: Electric twinprop aircraft	Aircraft 5: Electric regional aircraft
Aircraft characteristics					
Speed [km/h]	550	820	850	350	480
Seats	45	70	150	20	48
Average TAT [mins]	25	35	45	20	25
Additional charging time [mins]	--	--	--	20	45
Maximum range [km]	1,500	3,300	6,300	400	1,000
Runway required [m]	1,400	1,600	1,800	750	950
Cost					
Weekly lease cost [€]	15,000	34,000	80,000	12,000	22,000
Fixed operating cost C_X [€]	300	600	1250	90	120
Time cost parameter C_T [€/hr.]	750	775	1400	750	750
Fuel cost parameter C_F[gallon/km]	1.0	2.0	3.75	--	--
Batteries energy G^k[kWh]	--	--	--	2130	8216