Master Degree in "Ingegneria Informatica" and "Computer Engineering"
Università degli Studi di Genova

"Optimization and Control of Logistics Systems"

Team Working Activity on the Network Design Problem

Let us consider a German logistic provider which has two main big customers to serve, the former is a company producing shoes which needs to transport goods from Nantes, Paris and Hannover to Marseille, Milan and Prague, while the latter is a company which must deliver vegetables from Paris, Marseille and Prague to Nantes, Hannover and Milan.

The logistic provider has three logistic centers which can be emploied as transhipment nodes in the logistic network, located in Lyon, Frankfurt and Linz.

Referring to one year of activity, the number of 20' containers delivered and required by the different areas, for the two products, are summarized in the following tables.

Cities	Shoes: offer	Shoes: demand	Vegetables: offer	Vegetables: demand
Nantes	150	-	-	290
Paris	220	-	380	-
Marseille	-	270	180	-
Hannover	300	-	-	300
Milan	-	200	-	200
Prague	-	200	230	-

After a detailed analysis, the managers of the German logistic provider have defined the possible connections to activate among the different nodes of the network. First of all, the three transhipment nodes can be connected with each other, specifically Lyon can be connected with Frankfurt and Frankfurt with Linz, in both directions. Let us call these connections as "primary connections". As for the other nodes, they can be connected with transhipment terminals as follows (again considering the two directions): Nantes can be connected with Lyon and Frankfurt, Paris with Lyon and Frankfurt, Marseille with Lyon and Frankfurt, Hannover with Frankfurt and Linz, Milan with Frankfurt and Linz, Prague only with Linz. Let us call these connections as "secondary connections".

To estimate the main parameters of the problem, the company has considered one generic year of activity. The activation costs of the links have been estimated as equal to 70000€ for the primary connections and equal to 50000€ for the secondary connections. Note that this is the cost to activate the transport service, hence it is associated to a link (if the link between A and B is activated, and also the link between B and A is activated, this cost is paid twice).

The transportation costs have been estimated by the company considering that the unit cost in one arc connecting A and B is equal to the unit cost from B to A, and

also considering that the unit transport cost for delivering vegetables corresponds to additional 50€ due to the use of reefer containers. The following table reports the unit cost [€/container] for transporting shoes for each connection.

Connection	Unit cost
Nantes-Lyon	300
Nantes-Frankfurt	450
Paris-Lyon	300
Paris-Frankfurt	450
Marseille-Lyon	250
Marseille-Frankfurt	450
Milan-Frankfurt	350
Milan-Linz	450
Hannover-Frankfurt	250
Hannover-Linz	400
Prague-Linz	150
Lyon-Frankfurt	200
Frankfurt-Linz	200

Finally, the company has estimated the capacity of the logistic services as follows. The maximum number of containers that can be transported in the primary connections is equal to 2000 (1000 for each type of products), while it is 600 for the secondary connections (400 for each type of products).

The company is interested to decide which transportation services to activate over the possible links.

1. Write the mathematical programming formulation for this model (with data with their values, decision variables, objective function and constraints).

2. Implement this model: how many links are activated in the optimal solution? What is the optimal total annual cost?

3. Assume that, for some contractual reasons, the primary connections must be forced to be activated. How does the formulation change in this case? What is the optimal total annual cost in this case?