Problem 1.

List of transfers: (MULTIPLE OPTIMAL SOLUTIONS)

E-> A: 5 cars

F-> B: 8 cars

F-> D: 7 cars

451 minutes

Problem 2.

Väinö ja Emil

342 euros

Problem 3.

a)

$$\min \sum_{i=1}^{3}\sum_{j=4}^{7} c_{ij}x_{ij} + \sum_{i=4}^{7}\sum_{j=8}^{20} c_{ij}x_{ij}$$

$$\sum_{j=4}^{7} x_{ij} \le p_{\mathrm{i}},\ i \in \{1, \dots 3\}$$

$$\sum_{i=1}^{3} x_{ik} = \sum_{j=8}^{20} x_{kj}\ ,\ k \in \{4, \dots 7\}$$

$$\sum_{i=4}^{7} x_{ij} = d_j,\ j \in \{8, \dots ,20\}$$

$$x_{14} \le 900$$

$$\sum_{i=1}^{3} x_{i7} \le 5000$$

$$x_{ij} \ge 0$$

b) 3 490 420 euros

c) Arrows needed also from warehouses to countries

Problem 4.

a) $w = -2.1$

$$\min \sum_{j=1}^{20} (x_j(g_j + wb_j) + x'_j(g'_j + wb_j{}'))$$

$$\sum_{j=1}^{20}(x_j c_j + x'_j c'_j) - 3000s \leq 40000$$

$$x_j + x'_j \leq 1 \text{ , } j \in \{1, \dots, 20\}$$

$$x_{10} + x_{11} - 2s \geq 0$$

$$x_{10} + x_{11} - 2s \leq 1$$

$$x_j, x'_j, s \in \{0,1\},\ j \in \{1, \dots, 20\}$$

b) See spreadsheet

-298.9 tons and 152 species

Problem 5.

a) See Ohio banking example in lecture slides. For each municipality one constraint that ensures there is a clinic within 30 minute driving distance, e.g.., for municipality D: $x_B + x_C + x_D + x_F + x_G \geq 1.$ The constraints were required to be encoded with separate cell coefficients with the use of SUMPRODUCT or at least clearly labeled in adjacent cells (“Model not clearly represented -1pt”).

c) A,C,F; 9Meuros

Problem 6.

a) Link the transportation volumes to the binary decisions:

$$\sum_{i=1}^{4} x_{ij} \geq r_j y_j,\ j \in \{1, \dots, 7\}$$

+ Standard transportation problem capacity constraints

$$y_j \geq y_k,\ \ j \in \{5,7\},\ k \in \{1,2,3\}$$

+ Similar constrains between rank 2 and 3 cities

c) Frankfurt, Milan, Madrid, Vienna

d) 21 286 500 euros

Common pitfalls:

- Not writing the constraint for the prespecified number of new offices n in part a), although this constraint was mostly included in the solutions of part b)
- The demand constraints require the binary decision variables y_j in the RHS: only if an office is opened, then there will be experts transferred
- In part b) the variables representing the transfers should **not** be integers: the integral RHS of the demand constraints causes the transfer variable values to be integers as well. The computational load of the solution is significantly increased by integers variables, and in some cases could lead to inaccuracies of the final solution.
- Adding a budget constraint is unnecessary: the objective function already minimizes the costs.

- The binary variables y_j have to be formulated as decision variables in Solver as well.
- Many solutions had inconsistencies with the given mathematical formulation in part a) and the spreadsheet implementation in part b).