ME 44206 - Assignment Q1 - Individual
(25% of the final grade, a minimum of 5 is required to pass the course)
Due date: October 25, 2024

Steel is one of the easiest metals to be recycled. Every particle of scrap iron or scrap steel would actually help in making steel. The problem is when different metals are mixed, as it is very difficult to separate the metals in the scrap once it is mixed. Some metals are required, others are undesired. Chromium and nickel are often required, copper is considered an impurity which makes it look less shiny. In order to produce the required quality finding the correct mix of source material is crucial.

A company producing stainless steel for cookware buys scrap from different suppliers. Each supplier delivers material with a consistent mix of chromium, nickel, copper and iron. The table below describes the composition of the material, the maximum supply that can be delivered per month and the costs per kg for each supplier. The supplied material must be used in production in the same month it is delivered, in other words, scrap material cannot be stored.

Supplier	**A**	**B**	**C**	**D**	**E**
Chromium (%)	18	25	15	14	0
Nickel (%)	0	15	10	16	10
Copper (%)	0	4	2	5	3
Maximum per month (kg)	90	30	50	70	20
Cost (euro/kg)	5	10	9	7	8.5

The company produces stainless steel in 3 different types: 18/10, 18/8 and 18/0. The first number indicates the percentage chromium, the second number the percentage nickel. The demand for each of the 3 products for the following year is given in the table below.

Month	**18/10 (kg)**	**18/8 (kg)**	**18/0 (kg)**
Jan	25	10	5
Feb	25	10	20
Mar	0	10	80
Apr	0	10	25
May	0	10	50
Jun	50	10	125
Jul	12	10	150
Aug	0	10	80
Sep	10	10	40
Oct	10	10	35
Nov	45	10	3
Dec	99	10	100

The company plans a production schedule to meet this demand. Products that are not needed for the demand in a month can be stored. Holding costs are different for each product and paid at the end of each month. The total production capacity (for the 3 products together) is limited to 100 kg per month.

	18/10	**18/8**	**18/0**
Holding costs (euro/kg)	20	10	5

The company aims to optimize the production schedule in order to minimize the total costs.

a. **[30 points]** Provide the mathematical model in the form of an LP that would determine the optimal production schedule for these three products (**satisfying the demand**) throughout the year that minimizes the total costs. Indicate the parameters, decision variables, objective function and constraints clearly with their definitions and explanations.

Note: If the mathematical model has fundamental flaws at this stage the rest of the assignment may not be evaluated.

b. **[20 points]** Implement the mathematical model in part (a) in python and solve with Gurobi. Provide the optimal solution. By the optimal solution it is meant that you need to report the optimal cost value and the production schedule. Your python model needs to also output the values of the decision variables but only those that you discuss need to be in the report.

Note: You are expected to have the implementation in the matrix form and if the implementation fails that, the rest of the assignment may not be evaluated. Moreover, make sure that model and data are separated, i.e., values of the parameters are not assigned in the model itself. This is required to enable experiments with the same model but other data-sets; or with the same data but other modeling choices.

c. **[10 points]** Verify the implementation, to convince that the code for (b) matches the mathematical formulation of (a) with a number of verification tests that cover different types of parameters used in the model. Provide a discussion on the verification experiments and their results with your justifications.

d. **[20 points]** Experiment with different values of the maximum production capacity and the holding costs in order to get insights for the trade-off between these in the production and inventory holding decisions for products. Justify the ranges of values you use for the experiments. Provide your interpretation of the results by discussing the impact on the objective function, different costs involved and the decisions.

The company wants the amount of copper in its products to be below a certain value, called the CopperLimit. In order to remove copper from a mix, electrolysis can be used. Each month it is decided whether electrolysis will be used; if so, fixed costs for electrolysis must be paid (100 euro) in that month and the production of that month for each product can be treated. The weight reduction caused by electrolysis is equal to the weight of the copper that is removed. The variable costs for electrolysis depend on the amount of copper that is removed this way and is 5 euro per kg.

e. [20 points] Extend the mathematical model so that the use of electrolysis is included. Use binary decision variables and keep it as a mixed integer linear programming problem (no multiplication of variables with variables). Provide the changes in your mathematical formulation.
Use the model to determine the lowest CopperLimit that can be used without extra costs, compared to the solution for (b). Experiment with other values of the CopperLimit and show the effect it has on electrolysis costs and holding costs.

Submission guidelines:
Deliver a report in digital form (pdf or doc). Report the mathematical model in the standard presentation style; use of the provided template is recommended. **Do not include your python code in the report**; add the python file as a separate deliverable. You can either provide the final version of the python file where different versions corresponding to different parts above can be identified. Or you can opt for uploading different versions as separate files by indicating each part by "_b, _e …" in the file name. Do not discuss your code in the report but make your code self-explanatory and add comments to the code file. Make sure all your files are named with your last name and study number: thus **Lastname_12345678.pdf** and **Lastname_12345678.py**

This is an individual assignment.

Cooperation and discussion is allowed; nevertheless simply copying others' work is not! To test your understanding of the delivered report, an individual discussion with the supervisors might be part of the grading procedure. In case of suspected plagiarism, for instance if two identical python codes are submitted, the board of examiners must and will be informed. The consequences of this usually lead to significant delays in your study program as experienced before.

Use of generative AI/chatbots.

If you did not use a chatbot, a short statement in your report is sufficient.
In case you did use a chatbot for the assignment: write a clear statement, mentioning the name of the tool used. Per question, give the prompts used and how the answers helped you with that question.
Note: in some cases we will invite students for an interview about the delivered report as part of the assessment procedure.