

## ME 44206 - Assignment Q1 2021

Due date: October 29, 2021

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. In 18/10 steel (stainless steel for cookware), you need to have 18% chromium and 10% nickel. On the other hand, copper is an impurity which makes it look less shiny.

A steel company currently has a scrap yard with 10 different heaps (A to J) of scrap iron, identified in the table below. Each heap contains a consistent mix of chromium, nickel, copper and iron. An arbitrary portion of each heap can be used in a mix.

Heap	A	B	C	D	E	F	G	H	I	J
Chromium (%)	10	25	25	14	0	18	10	2	25	10
Nickel (%)	0	15	10	16	15	1	12	8	19	2
Copper (%)	4	0	2	5	3	0	1	3	0	15
Amount (ton)	30	90	50	70	20	30	10	20	5	100
Cost (euro/ton)	50	100	90	70	85	115	90	80	105	15

The company produces steel of 18/10 quality: at least 18% chromium and 10% nickel. Furthermore, the content of iron must be at least 65% for each batch. The product is available in 5 different grades; grade 1 has the highest copper content, grade 5 contains no copper at all. The different grades and the maximum copper content is given in the table below.

Grade	1	2	3	4	5
Max copper (%)	5.0	2.5	1.0	0.5	0.0
Holding costs (euro/ton)	10	12	15	18	25

The company plans a production schedule for 6 months. In each month, the production for each grade is determined as a mix from the different heaps. In each month, the production of a grade that is not needed for order delivery in that month can be stocked. Therefore the stock of a grade can consist of slightly different compositions (produced in different months) but the production in each month must satisfy the rules for each grade as given above. Holding costs are different for each grade and paid at the end of each month.

Month due	Grade	Quantity (ton)
Jan	1	5
Feb	5	20
Mar	4	80
Apr	3	25
May	2	50
Jun	1	125

The order portfolio for 6 months is known and is given in the table above.

- a. **[20 points]** Provide the mathematical model that would determine the optimal schedule for these 6 orders throughout the half 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 provide the optimal objective function value, the separate costs components and a clear overview of all the related decision variables.  
**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. This is required to enable experiments with the same model but other data-sets; or with the same data but other model choices.

Now consider that there is a monthly production capacity limit. The maximum production each month is 75 ton (bruto, before electrolysis).

- c. **[10 points]** What would change in the formulation? Provide the new additions/changes to the mathematical model. What would be the new optimal solution? Discuss the changes in the results (compared to part b) together with your reasoning.
- d. **[15 points]** Verify the mathematical formulation (part c) 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.

Electrolysis can be used to remove copper from a mix. Each month it is decided whether electrolysis will be used; if so, fixed costs for electrolysis must be paid (500 euro) in that month and the production of that month for each grade 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 varies per month and are given per kg of copper that is removed this way.

Month	Jan	Feb	Mar	Apr	May	Jun
Variable electrolysis costs (euro / kg)	0.10	0.20	0.30	0.40	0.20	0.10

- e. **[15 points]** What would change in the formulation? Provide the new additions/changes to the mathematical model. What would be the new optimal solution? Discuss the changes in the results (compared to part b and d) together with your reasoning.
- f. **[10 points]** Experiment with different values of the cost and configuration parameters in order to get insights for the trade-off between material, electrolysis and inventory holding decisions. Justify the values you use for the experiments, showing significant impact on the solution, and provide your interpretation of the results.

The steel company wants to move after June and therefore has a second objective of emptying the scrapyard by producing extra steel in any grade.

- g. **[10 points]** Modify the model to study the relation between total costs, steel inventory and size of scrap yard at the end of June.

## Submission guidelines

Deliver a report in digital form (pdf or doc). **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 “\_a, \_b ...” 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; however, cooperation and discussion is allowed; but 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 the exam committee must and will be informed.*