ME 44206 - Assignment Q1 (25% of the final grade, a minimum of 5 is required to pass the course)
Due date: October 30, 2020
Workload: 10-20h depending on the prior mathematical modeling and programming experience

A manufacturing facility is producing 3 products and the demand for these products (units of finished products) throughout the year is given as follows:

Prod \ Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
1	650	600	600	550	500	500	450	600	650	600	600	550
2	200	250	250	300	350	400	400	500	500	400	300	250
3	300	350	400	350	300	400	400	300	350	350	300	350

These products are produced through 4 different operations. Each product goes through 2 successive operations and the corresponding operations needed for each product is provided below together with the needed time on each operation. For example, product 1 goes through first operation I and then II and producing a unit of product 1 takes 0.6 hour on operation I plus 0.8 hour on operation II.

Product \ Operation	I	II	III	IV
1	0.6h	0.8h		
2		0.3h	0.9h	
3	0.4h			0.7h

Over production of either the semifinished product or the finished product for each of the products in any month is allowed for use in a later month. The corresponding holding costs are provided in the table below. Note that, for product 1 semifinished product corresponds to the stage after operation I and it is finished after operation II. Product 2 is semifinished after operation II and finished after operation III. Finally, product 3 is semifinished after operation I and finished after operation IV.

Products	Semifinished Holding cost (euro)	Finished Holding cost (euro)
1	2	4
2	1	3
3	1	4

The cost of production (euro) for each operation varies throughout the year as follows:

Oper. \ Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
I	12	11	11	11	10	8	9	12	16	18	18	14
II	18	25	25	20	15	15	17	19	19	18	18	18
III	10	12	11	12	11	12	12	12	12	11	11	12
IV	8	9	12	13	15	15	18	15	10	8	8	8

a. **[20 points]** Provide the mathematical model that would determine the optimal schedule for these 3 products on 4 operations 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 provide the optimal objective function value, the total holding and production costs.
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.

c. **[15 points]** Now consider that there is a monthly capacity limit for each of the operations throughout the year and given as 550h, 750h, 450h and 400h for operation I, II, III and IV respectively. 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. **[10 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.

e. **[10 points]** Experiment with different values of the production and holding costs in order to get insights for the trade-off between production and inventory holding decisions. Justify the values you use for the experiments and provide your interpretation of the results.

f. **[15 points]** Building up on the formulation in part c, now consider that each of the machines used for the operations needs to go through a revision in one (and only one) of the months. Note that revisions for different machines can take place in different months. During the month of revision, the associated operation cannot be performed and therefore the new formulation needs to decide on the month of revision for each of the operations. Provide the new additions/changes to the mathematical model and provide the new optimal solution. How does the model decide on when to perform the revision for different operations and why? How do the other decisions change compared to part c and why? Explain your understanding and insights.

g. **[5 points]** For the formulation you have in part f, now assume that thanks to the performed revision, the production cost thereafter (i.e., for the months after the revision) reduces for the corresponding operation by a factor of 10%. Provide the new additions/changes to the mathematical model. What is the new optimal solution? How did the decision on when to perform the revision change (compared to part f) and why? Provide your insights explaining the trade-off across decisions.

h. **[5 points]** In part g, you are provided with a reduction factor of 10%. Now experiment with different values of this factor and report the different solutions. Justify the values you use for the experiments and interpret the results considering the trade-off across decisions.

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.