42401: Project One

September, 2015

Question One

Part A

You are employed by a small consultancy specializing in Operations Research, Statistics, and Planning. You have been approached by the company GroundCo, who provide ground crew services at the nearby airport. GroundCo is looking to reduce the cost of their ground crew schedules and have asked you for advice on how best to optimize the use of their employees.

GroundCo operates 24 hours a day, seven days a week. The number of ground crew needed at any given time fluctuates over the course of a day (typically in line with the volume of flights arriving and departing at the airport) and its employees must be assigned to *shifts* in such a way that, collectively, there is always enough staff on hand and, ideally, the financial cost of the shifts used is minimized. A shift is a continuous interval of time, eight hours in duration. Multiple employees can be assigned to any given shift. Current union legislation states that employee shifts can only begin at hourly intervals (i.e. 12am, 1am, 2am, 3am,..., 11pm) and must contain a one hour meal break. GroundCo has agreed with the union that the meal break should be placed after three hours of work, or after four hours of work.

GroundCo have asked you to determine the best possible set of shifts. In determining this you are also to decide on when to place the meal-breaks within the shifts (given the two options above). GroundCo currently can allocate no more than 155 employees in any 24 hour period and need to determine how many employees to assign to each shift. The final set of shifts must collectively provide the required staffing levels over the course of a typical day. These levels are given at one hour intervals and are specified in Table 1. Since you are considering data for a typical day, you should assume that any shift starting within eight hours of midnight also covers the demand periods in the early part of the following morning.

00:00 - 01:00	4	06:00 - 07:00	58	12:00 - 13:00	64	18:00 - 19:00	56
01:00 - 02:00	4	07:00 - 08:00	64	13:00 - 14:00	61	19:00 - 20:00	38
02:00 - 03:00	4	08:00 - 09:00	64	14:00 - 15:00	60	20:00 - 21:00	19
03:00 - 04:00	4	09:00 - 10:00	54	15:00 - 16:00	58	21:00 - 22:00	11
04:00 - 05:00	18	10:00 - 11:00	54	16:00 - 17:00	53	22:00 - 23:00	4
05:00 - 06:00	52	11:00 - 12:00	62	17:00 - 18:00	55	23:00 - 24:00	4

Table 1: Hourly staff required

In terms of cost, employees are paid 240 DKK/hour and must be assigned an eight hour shift. Meal breaks are not paid. From both an administrative as well as a practical perspective, shifts that start late in the evening or shifts that start very early in the morning are undesirable. GroundCo have stated that any shift starting in the interval $[11\text{pm}, 4\text{am})$ costs 25% more per hour than shifts starting at other times. Finally, there is a fixed administrative cost of 1000 DKK in using a shift, irrespective of how many employees are assigned to it.

1. Formulate a mathematical model that can be used to optimize GroundCo's staff scheduling and shift selection problem.
2. How many decision variables and constraints are there?
3. Using OpenSolver, find the optimal solution to GroundCo's problem. You should report the number of shifts used, the number of employees assigned to each shift and the total minimum cost.
4. How much employee overcoverage is incurred in your solution? Overcoverage is incurred whenever the number of staff in a given period exceeds the level required.

Part B

Recent negotiations with the employee's union have given GroundCo permission to also run four hour shifts. A four hour shift must adhere to the same requirements as an eight hour shift, with the exception that no meal break is required.

6. Extend your formulation from Part A2 to account for this possibility
7. What is the optimal mix of 8-hour and 4-hour shifts
8. How many staff are required in this case, and what level of overcoverage is incurred in your solution?
9. Explain your observations to Questions A4 and B8.

Part C

GroundCo is of the opinion that too many different shifts is, from an administration perspective, difficult to oversee. They would like to limit the number of shifts to at most 10.

10. What do you recommend?
11. Discuss briefly how you could extend your model to ensure that certain time intervals are more preferable to overcover than others.

Note: Please attach the spreadsheets you have used to obtain your results.

Job	1	2	3	4	5	6	7
Release Date	2	5	4	0	0	8	9
Processing Time	5	6	8	4	2	4	2
Due Date	10	21	15	10	5	15	22

Table 2: Job information

Question Two

A set of jobs is to be processed on a single machine. The execution of the job is non-preemptive (i.e. a job cannot be interrupted before its completion). Information regarding the release date, processing time, and due date for every job is given in Table 2

1. How many unique sequences are there for the seven jobs?
2. Formulate a MIP model which minimizes the **makespan** of the seven jobs
3. Solve your model using OpenSolver. Report the optimal solution. Is this unique?
4. For each of the following objective functions, find a job sequence that minimizes it. For each objective function, you should indicate any changes that are required to your initial model.
   (a) The **minimum sum of the completion times** for each of the seven jobs
   (b) The **minimum number of tardy jobs**
   (c) The **total minimum tardiness**

Note: Please attach the spreadsheets you have used to obtain each result.

Question 3

Lyngby Metals is a small manufacturing company that produces hard metal tools used in various industries. It had one production line dedicated to the manufacture of rectangular stainless steel profiles, but because of strong demand Lyngby Metals recently added a second line. The new line provides higher-capacity automated equipment but consists of the same basic four processes as the old line. Furthermore, the new line has two parallel machines per work station, while the old line has mainly a higher number of parallel machines at the work stations. The processes, along with their machine rates, number of machines per station, and average process times for a lone job to go through a work station (i.e. not including queue time), are given for each line in Tables 3 and 4, respectively.

Over the past 6 months, the old line has on average 1260 parts per day, where one day consists of one 8-hour shift, and has had an average WIP level of 1600 parts. The new line has averaged 2720 parts per 8-hour day with an average WIP level of 1400 parts. Management has been dissatisfied with the performance of the old line because it is achieving lower throughput with higher WIP than the new line. Your job is to evaluate these two lines to the extent possible with the above data and identify potentially attractive improvement paths for each line by addressing the following questions.

Process	Throughput rate per Machine [parts/ hour]	Number of Machines per Station	Average Process Time of Workstation (without queue time) [minute]
Cutting	30	8	8.0
Bending	24	8	10.0
Assembly	40	4	6.0
Finishing	100	2	2.4

Table 3: Old Production Line Details

Process	Throughput rate per Machine [parts/ hour]	Number of Machines per Station	Average Process Time of Workstation (without queue time) [minute]
Cutting	240	2	1.00
Bending	210	2	1.00
Assembly	250	2	0.96
Finishing	250	2	0.96

Table 4: New Production Line Details

1. Calculate for **both** production lines
   (a) $r_b =$
   (b) $T_o =$
   (c) $W_o =$
   (d) Which line has the larger critical WIP? Explain your answer briefly in one or two sentences.
2. Compare the performance of the two production lines to the practical worst case. What can you conclude about the relative performance of the two production lines compared to their underlying capabilities? Is management correct in criticizing the old line for inefficiency?
3. If you were the manager in charge of these lines, what option would you consider first to improve throughput:
   (a) of the old line?
   (b) of the new line?

   Please answer briefly in one or two sentences.

Appendix: General Information

- The deadline for handing in the report is Friday October 9th, 23:59
- CampusNet **must** be used for handing in the report
- The project must be done in groups of 4-6 students. If two groups collaborate on the project, this must be stated clearly in the text. "Cut and paste" of text from other groups is regarded as copying.
- Just one member of the group needs to hand-in the report via CampusNet.
- Print the name and student number of all group members on the front page of the hand-in.
- The length of the report should not be more than 15 pages. Please try to be as concise as possible.
- You are allowed to use whatever solver software you prefer, e.g., OpenSolver, GAMS, Cplex etc. The teachers and teaching assistants can only be expected to be familiar with OpenSolver.
- Besides the report you must hand in documentation of how you achieved the solutions (e.g. Excel spreadsheets, GAMS files, Cplex models etc.)
- Note that the documentation mentioned above (OpenSolver, GAMS, Cplex files) alone is not sufficient to answer any questions
- Make sure to answer the questions explicitly in the report
- Please be thorough with your notation. Do not write $\sum_i x_i$ or even $\sum x$, but instead $\sum_{i \in I} x_i$.
- *Guiding* weights of the questions:
  - Part A: 50%
  - Part B: 30%
  - Part C: 20%
- This and the following assignment constitute an essential part of the final grade