Optimization HW7

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Exer 1

Build the optimal routes for customers in Manhattan. This problem is motivated by a same-day delivery problem. The file manhattan_customers.csv has the depot as ID=1 and then the 20 customers that need to be delivered right away. Assume that each vehicle has a max number of stops of 3. The notebook called "Helper Routing Functions" provides you with some formulas for calculating distance and for building a distance matrix. Don't worry about cost, just focus on minimizing distance. Assume that vehicles that leave the depot have to return to the depot.

In total, there were 3,630 distinct routes to choose from. The solver chose the following solution:

```
Status: Optimal
13_17_16 is one of the chosen routes
15_14_18 is one of the chosen routes
2_19 is one of the chosen routes
3_5_6 is one of the chosen routes
4_20_11 is one of the chosen routes
7_12_21 is one of the chosen routes
9_8_10 is one of the chosen routes
The model selected a total of 7 routes
Total Distance =  50.724607
Total Runtime was 2.64 seconds
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Exer 2

a. **What is the makespan under the SPT dispatching rule (use the time for Shear as the processing time)**

   The following tables shows total processing times for shearing (34) and pressing (40).

Job	Shear	Press
4	1	1+8=9
2	1+2=3	9+9=18
6	3+4=7	18+5=23
3	7+5=12	23+3=26
1	12+6=18	26+3=29
5	18+7=25	29+1=30
7	25+9=34	34+6=40

b. **What is the sequence that yields the minimum makespan and what is this time?**

We applied Johnson's Rule to minimize the makespan.
Job 4 has the minimum processing time for shearing, so it will be the first job. Job 5 has the minimum processing time for pressing, hence it will be the last job.

Job	Shear	Press	Order
1	6	3	
2	2	9	
3	5	3	
4	1	8	1
5	7	1	7
6	4	5	
7	9	6	

Job 2 has the second shortest processing time for shearing, so it will the second job. Job 1 and Job 3 are tied for the second shortest processing time for pressing; we can arbitrarily choose which one will be next to last and which one will be second to last.

Job	Shear	Press	Order
1	6	3	6
2	2	9	2
3	5	3	5
4	1	8	1
5	7	1	7
6	4	5	
7	9	6	

Job 6 has the third shortest processing time for shearing, so it's the third job. Job 7 ends up being the 4th job.

Job	Shear	Press	Order
1	6	3	6
2	2	9	2
3	5	3	5
4	1	8	1
5	7	1	7
6	4	5	3
7	9	6	4

The following tables shows total processing times for shearing (34) and pressing (36). Notice that the total shearing time will always be 34 periods. Also, notice that the sum of all "pressing" processing times is 35 periods. The minimum possible idle time for the pressing machine is 1 period. Hence, no solution can yield a total makespan that is less than 36 periods. We have therefore found a solution that yields the minimum possible overall processing time.

Job	Shear	Press
4	1	1+8=9
2	1+2=3	9+9=18
6	3+4=7	18+5=23
7	7+9=16	23+6=29
3	16+5=21	29+3=32
1	21+6=27	32+3=35
5	27+7=34	35+1=36

Exer 3

Consider the jobs in the table below. Process times for all jobs are 1 hour. Changeovers between families require 4 hours. Thus, the completion time for job 1 is 5, for job 2 is 6, for job 3 is 11, and so on.

a. **Compute the total tardiness of the sequence**

Job	Family Code	Due Date	Completion Time	Tardiness
1	1	5	5	0
2	1	6	6	0
3	2	12	11	0
4	2	13	12	0
5	1	13	17	4
6	1	19	18	0
7	1	20	19	0

8	2	20	24	4
9	2	26	25	0
10	1	28	30	2
			Total Tardiness	10

b. How many possible sequences are there?

10! = 3,628,800

c. **Find a sequence with no tardiness.**

The following sequence gives a total tardiness of 0.

Orders	Family	Due Date	Completion	Lateness	Tardiness
1	1	5	5	0	0
2	1	6	6	0	0
5	1	13	7	-5	0
3	2	12	12	-1	0
4	2	13	13	0	0
8	2	20	14	-5	0
6	1	19	19	-1	0
7	1	20	20	0	0
10	1	28	21	-5	0
9	2	26	26	-2	0

Exer 4

(Business Strategy Question). Why do you think a scheduling system will work better in a low utilization environment (a low utilization environment is one where production capacity is much higher than demand or where the number of workers is much higher than the load placed on the workers)? Assume you have developed and implemented a great scheduling system in a medium to high utilization environment—that is you are getting more jobs through the factory and the jobs are on time or early. What do you think would change (because of your great work) with the business environment that might make the scheduling system perform poorly? (Think about the entire firm from the CEO's perspective.)

Part 1:
A scheduling system in a low utilization environment will have fewer constraints on resources and capacity than a high utilization environment, which makes the system perform better.

A low utilization environment also allows to reduce costs by cleverly designing ways to meet demand via bulk production instead of constant/regular manufacturing. Scheduling can be an extremely powerful tool to achieve these costs reductions

Part 2:
The scheduling system's performance is measured in terms of the number of jobs getting through the factory and if the jobs are on time or early without taking into account the work life balance and the physical/mental effort that goes into manufacturing different types of products. In the long run this can create fatigue among the workers, negatively affecting their productivity, and possibly leading to higher turnover rates. Since the scheduling solution is designed to meet all the demand on or before time, unplanned absences might disrupt the whole schedule since it would require workers to fill in for each other.

Exer 5

(Intuition Question): Assume you have built a very good scheduling system (or any optimization system) for a very hard problem. And, let's say to build this system, you had to decompose the model into different sub-problems. The solution isn't the global optimal and never can be (because it is a hard problem). What if the user of your system looks at your results and can easily find things to change to create a better solution. Does this invalidate your good solution? Why or Why Not?

This would invalidate the overall solution, even if does not invalidate any one of the single submodels. The combination of N optimal solutions is not necessarily going to be optimal, as the interactions between the different parts of the problem are not taken into consideration by any one of the various models. Hence, even if the single models have been solved optimally, this might signal that mistakes were made when choosing how to approach the problem. The modeller might have decided to split the problem into too many subproblems; we suggest rethinking the design of the solution, going back to the original business question and find a different way to approach the problem. It could be the case that reducing the number of subproblems would lead to too-big of a problem or that no other split into subproblems would lead to feasible problem; in that case, we would suggest combining the results from the optimization with intuitions from the business and SMEs.

Exer 6

Picture a large hospital. If you were to implement an optimal nurse scheduling system, what might it look like and how would it work? I'm looking for a clean write-up, but you don't have to actually create any models.

Let's start by considering the objective function we would need to optimize. Nurse scheduling is a difficult, high-stakes problem with multiple objectives. First, you need to optimize the number of nurses working at any given time: minimize number of nurses scheduled (minimize cost), maximize patient satisfaction with the service provided by nurses (this could mean minimizing patient wait from check-in to service or optimize other metrics). The chosen solution would have to meet a series of constraints: you may have restrictions on the maximum number of available nurses (hiring new nurses is not an option in the short term) and a minimum number of nurses that needs to be scheduled at one time (for example, to make sure that we meet the expected demand for nurses and because of regulations and requirements).

At this point, you should have an idea of how many nurses you should be employing for each type of nurse that supports your hospital, but you might still want to minimize the number of total nurses to employ, or minimize labor cost directly. You may have constraints about nurses working two or certainly three shifts in a row.

Once those problems are solved, you will need to actually assign nurses to each of the slots, including nurses who are on call and backup call. You would need to avoid scheduling too many inexperienced nurses at the same time. You must also consider specialty training of the nurses, including OR and ER nurses, Oncology, Neonative, etc., as a large hospital would have several wards, and few types of nurses can work across specializations. These would be just some of the many restrictions on the model. If you did not completely restrict double shifts, you could minimize the number of them as your objective function. You could also maximize the average years of experience of nurses working at any given time. You may also simply want to minimize overtime hours

In practice, you would need a replicable schedule because daily/weekly changes will be decrease nurse satisfaction, but you may not have a tangible measure of nurse satisfaction to include in the model.