Operations Research Models and Methods

ORMM-Project - Academic Year 2023-2024

A Two-Tier Van-Bike System for Medical Supply Deliveries

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Instructions: - Submit your group's report (Group-xx_ORMM-Project_report.zip) as a single zipped file, which must contain **a pdf-report** and a **self-contained Jupyter Notebook** answering thoroughly the questions and reporting completely your results.

Farma18 is a medium-sized company which operates a medical supply warehouse in Drongen, a municipality of Ghent, Belgium. The warehouse is intended to mainly supply 16 major pharmacies in Ghent's inner city which signed up to the service. The management board of the company has decided that they would not outsource the distribution of the medical supply. They considered that it was possible - and more beneficial - to plan and perform distribution themselves. Three years ago, they hired a group of UGent engineers, experts in ORMM, to design the distribution system. It was determined that customers would be served by delivery vans, which perform fixed daily tours early in the morning to cover all pharmacies. If a pharmacy faces a shortage of certain product during the day, an emergency delivery could be arranged. The demand of each customer was analysed and the tours were optimised accordingly. The pharmacies were very satisfied with the service level, and the management considered the costs to be adequate.

Since May 2017, however, the company starts to receive complaints from the pharmacies it serves almost every day. These are clearly not as satisfied as before. They report that the vans arrive late in the morning, often with insufficient quantities. Workers are idle waiting for the vans, people who try to buy products before going work are not served on time, and many emergency deliveries must be arranged during the day.

Internally, the company also found that the distribution costs per unit of product distributed have significantly increased. At first, the company thought that this was the consequence of the more frequent emergency deliveries, but a deeper analysis has shown that the costs of the fixed tours had significantly increased too.

On Friday, November 10, the situation deteriorated. Tolhuis, one of the most valuable customers of Farma18, sent a final warning: "if you don't guarantee a service level of 95%, we'll stop doing business with you", warned the manager.

Farma18's vice-president, Mr. Rudy Bauwens, was afraid that same warning would be received from other customers. He called the sales manager Mrs. Lynn Goethals, the logistics director Mr. Jan Gerges and customers relations manager Mr. Giuseppe Cipollone to discuss the urgent matter.

Mrs. Goethals, a very proud and self-assured woman, was the first to speak. "In the last two years ago, since I became head of the sales department, the demand for our products has grown 80%. I thought we doing quite well".

“We indeed did very well, until some months ago.” - said the vice-president. “It seems that our current logistic system is not capable of coping with this high level of the demand anymore. How do you see this problem, Jan?”

Mr. Gerges replied with his usual, calm voice. “Well, in my opinion, the high demand is just another complicating factor”. The others looked puzzled, and he went on to explain. “The demand is a parameter of the model created by the engineers from UGent. I can enter a value, and the computer tells me how much I should load in each vehicle before each tour. I believe we are indeed very close to our capacity limits, given the size of the vans we use”. After taking a sip of his coffee, he added: “But note that I said *very close*. If we were working in the same environment as before, it would probably be sufficient”.

“What has changed?” - asked Mr. Bauwens.

“First, the parameters used to calculate the routes are not accurate anymore. The city has implemented a new mobility plan: *Het Circulatieplan*. In short, the inner city is divided into sectors. If two pharmacies lie in two different sectors, the van serving both must now drive through the ring R40. So our tours became much more longer, and the order in which the customers are visited is possibly not optimal anymore”.

Mr. Cipollone exclaimed: “This is why our vans arrive late at the customers!”. Mrs. Goethals added: “Indeed, driving by car in Ghent is very challenging nowadays. Luckily I can commute by bike”. Mr. Bauwens was curious to listen more from Mr. Gerges. “And what more has changed, Jan?”

“The demand has not only increased but its variability has also increased. Maybe Mrs. Goethals and Mr. Cipollone can provide more detailed information on these two aspects.”

“It’s true”, Mr. Cipollone said. “We monitored the market and listened to the customers. Most competitors ask for minimum delivery quantities. So the pharmacies had to accumulate orders and request them in batches. As a result, some of their customers had to wait longer to get the products. Following the lines of our aggressive sales strategy, we dropped this requirement. Every time we visit a customer, we fill their local inventory completely. It worked: we expanded our market share and increased the sales, as Mrs. Goethals already mentioned. But the short-term fluctuations on the demand have a direct impact on the actual order sizes, indeed.”

“Yes. Also, we only know how much a pharmacy needs at the time of delivery.” Mr. Gerges added. “We cannot load the vans with the exact quantity. Sometimes it happens that we do not have enough in the vans”.

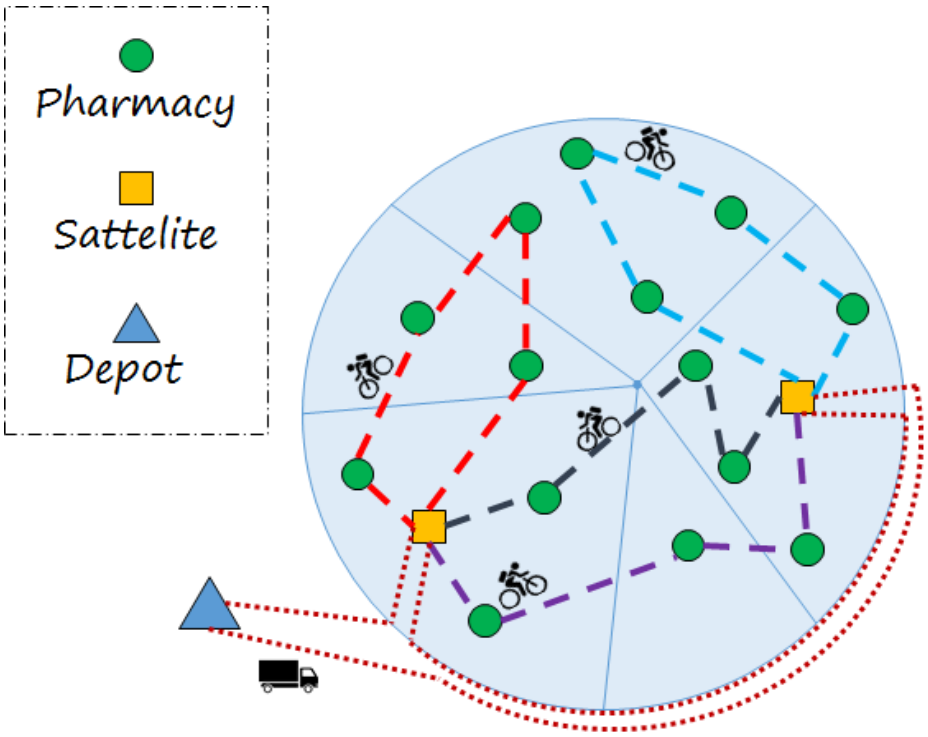
Mr. Cipollone went on: “And now we allow the customers to define time windows for the deliveries. This has a significant impact on how the routes must be planned and, consequently, on the transportation costs”.

“Interesting. I overlooked all these details when I agreed with the sales strategy. What do you think we should do now? Rent more vans? Change the strategy?” - asked Mr. Bauwens.

“If we rent more vans, we are going to make traffic even worse in Ghent. This isn’t aligned with the vision of the company on environment and sustainability. If on the other hand we change the sales strategy we might lose a part of our current market share.” - replied Mr. Gerges. “I have another idea. Let’s rethink the distribution system. ”

"How?". Mr. Bauwens was very curious.

"We can work with a two-tier system. The vans will bring the products from our *depot* to intermediate facilities in the city, which we can call *satellites*". From there, they should be delivered to the pharmacies by bikes. This way we will minimize the impact of the *Circulatieplan* on our distribution system." Mr. Gerges got up from his chair, went to the white board in the meeting room and depicted the following drawing:



"This is more or less what I have in mind, he said."

"Don't you think it will be too expensive to implement this distribution plan? We'll need to rent places to use as satellites…" - argued Mr. Bauwens.

"I think I have the solution to that" - exclaimed Mr. Cipollone. "Some of our customers have space in their back rooms which we could use to store products. They have already offered me that for relatively low fees."

"This sounds good." - said Mr. Bauwens. "What about the bikes? We can't hire a lot of full-time employees…"

"I think we can hire students for this job" - replied Mr. Gerges.

Mr. Bauwens thought for a minute. "Ok! I'm not 100% convinced, but I want to see this plan fully described. Then I can make a decision. This is your task, Jan. Giuseppe and Lynn will provide you with the data you need. Your deadline is December 08."

Mr. Gerges called the engineers who have helped the company three years ago, but they were too busy in their current jobs. They suggested to contact the students of *Operations Research - Models and Methods* and ask for assistance.

Your task is to help Mr. Gerges developing Farma18's distribution plan. You'll find more information in the annexes.

If you think you need more information than what's available here, make your own assumptions. Also, if the problem becomes too complex to model or to solve in a single step, try to divide it into smaller parts. You can make simplifications and use heuristics if you think it is necessary.

Your report must contain:

- A concise description of the problem;
- Your assumptions and simplifications;
- Answers to the questions 1 to 6;
- The mathematical model(s) and theoretic background you used to approach the problem;
- A detailed description of the model(s) and solution(s). It should be comprehensible for people who are not familiar with Operations Research.
    - List and explain the model parameters, decision variables, objective function(s), and constraints.
    - Map the routes, list the costs, describe the strategies, etc.
- Submit your group's report (**Group-xx_ORMM-Project_report.zip**) as a single zipped file, which must also contain a self-contained Jupyter Notebook (readable with visual studio code) answering thoroughly the questions and reporting completely your results, as well as any file necessary to run the code parts in the file.

Questions:

1) Write an optimization model (or algorithm/solution approach) for the problem using the average demand of each customer. Name the variables and parameters and do not use the actual values in your expressions (e.g. use N → number of pharmacies (instead of 16), d_i → average demand of pharmacy i, t_{ij} → travel time from pharmacy i to pharmacy j).

2) Is the model linear? If it is not, can you linearize it?

3) Solve the problem (using the average demand). If you cannot find a solution using the model/algorithm/solution approach described in (1), you can reformulate, adapt or simplify it.

4) Use your solution in 3 and simulate a number of scenarios for the actual demand, taking the variability into account. What is the service level (planned deliveries/actual demand)?

5) Which approaches or strategies would you consider in order to increase the service level (without changing the model/solution approach used in (3))? You can adapt the parameters (e.g. add a margin to the average demand) and/or elaborate contingency measures (e.g. emergency deliveries). Give an estimation of the costs.

6) How would you include a desired service level and the variability of the demand in the optimization model? If you are able to do it, solve the problem using your approach.

ANNEX 1 - Mrs. Goethals' data

	Demand - SEP 2018														
Day→ Pharmacy↓	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1	26	10	10	25	29	4	20	21	32	12	12	27	14	19	19
2	25	43	23	35	33	37	15	32	29	34	29	27	25	24	44
3	24	34	22	25	21	22	29	30	22	36	22	22	30	29	29
4	19	20	21	21	19	21	27	26	14	13	18	15	30	31	21
5	27	20	32	23	29	32	33	28	29	28	31	24	33	28	28
6	27	36	30	22	28	26	31	21	24	24	21	28	16	20	25
7	22	26	29	25	35	32	36	44	21	39	35	26	32	24	41
8	40	36	26	31	20	23	33	34	30	29	39	35	28	22	40
9	27	34	-6	13	21	25	25	10	13	26	5	10	25	29	22
10	28	23	28	26	23	23	19	28	23	28	27	27	33	29	19
11	17	26	22	44	21	33	36	22	28	30	47	30	42	41	40
12	25	31	19	32	33	28	20	24	23	17	20	28	25	22	22
13	22	22	26	32	29	17	32	21	21	26	25	33	30	20	28
14	21	10	8	3	21	21	24	8	28	15	27	24	12	20	14
15	9	10	26	14	23	5	10	9	18	10	15	8	17	7	14
16	22	15	19	18	17	23	24	15	13	11	15	18	13	28	14

	Demand - SEP 2018														
Day→ Pharmacy↓	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
1	20	26	21	18	30	28	8	24	16	20	5	22	19	18	10
2	32	40	37	28	26	29	34	28	27	34	25	38	35	26	28
3	13	28	27	27	24	28	30	30	20	23	27	27	30	31	31
4	18	26	16	20	23	15	28	12	17	20	14	8	18	13	11
5	25	31	35	27	32	32	22	35	28	28	40	35	24	33	28
6	24	27	28	30	26	24	22	24	28	27	23	27	28	22	11
7	38	31	20	35	28	30	33	40	32	41	26	37	33	38	25
8	21	30	35	22	13	21	27	21	27	33	38	23	9	19	29
9	26	20	10	30	18	19	25	7	25	14	13	15	30	22	26
10	21	13	42	29	24	24	30	27	24	26	21	31	24	28	25
11	26	44	37	26	16	29	31	30	31	38	26	31	32	35	36
12	22	11	18	34	17	29	29	20	16	25	25	24	15	17	20
13	19	22	22	29	21	28	21	24	25	25	23	24	20	22	26
14	19	10	22	12	22	25	19	2	12	28	23	11	21	12	16
15	17	13	26	18	6	24	13	14	16	14	9	15	21	8	26
16	21	20	13	20	20	22	22	13	23	10	22	26	25	15	14

ANNEX 2 - Mr. Cipollone's data

Possible satellites		
Pharmacy	Capacity	Cost/day
2	120	€ 60
4	150	€ 120
8	180	€ 130
13	100	€ 50

Remark: price includes the infrastructure for the bikes (parking, etc.). Do not choose more than three satellites.

Delivery Time windows		
Pharmacy	From:	To:
1	7:00	11:00
2	10:00	14:00
3	8:00	13:00
4	7:00	10:00
5	11:00	17:00
6	9:00	15:00
7	10:00	17:00
8	8:00	12:00
9	10:00	15:00
10	7:00	12:00
11	7:00	10:00
12	11:00	15:00
13	8:00	12:00
14	10:00	16:00
15	7:00	17:00
16	8:00	12:00

Remark: emergency deliveries can be made out of the time windows.

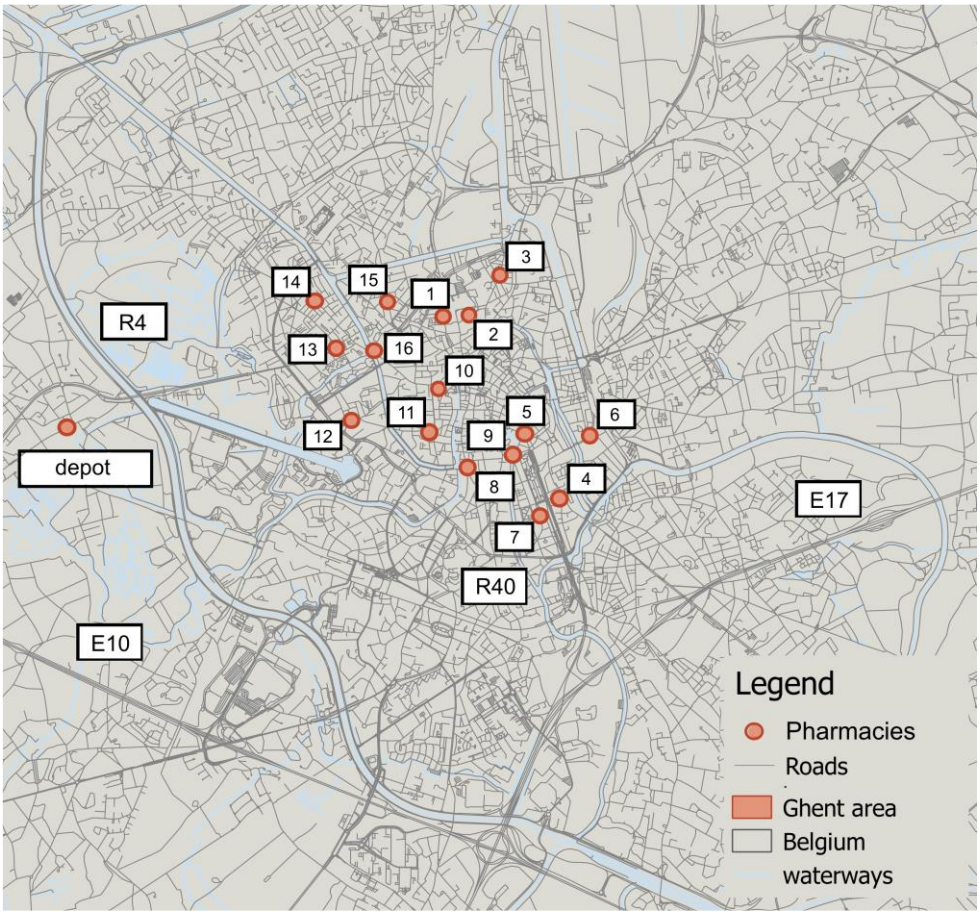
ANNEX 3 - Mr. Gerges' notes

- Delivery vans
    - 5 vans/drivers are available (from 7am to 4pm)
    - Capacity: 200 units
    - Costs:
        - Dispatching:
            - Planned morning trip: 100 euros per ride
            - Planned day trip: 150 euros per ride
            - Emergency delivery: 200 euros per ride
        - Per delivery: 25 euros
        - Variable costs: 0.80 euro/km
    - Loading at depot: 20min
    - Park and unloading: 10min
    - Planned trips: only to satellites
    - Emergency trips: to satellites or directly to the customers

- Bikes
    - 2 hours/day per student (starting any time from 8am to 4pm)
    - We can use as many bikes as we want/need
    - Capacity: 80 units
    - Costs
        - Material, maintenance, student wage and admin. costs: 150 euros/bike/day
    - Loading: 10min
    - Unloading: 5min

- The same tours should be performed every day (i.e. we need a basic daily plan)
- In normal conditions (i.e. average demand), the inventory at the customers should be filled before 10am.
- Bikes can be reloaded at different satellites, but they must start and end the day at the same satellite, so that the cycle can be repeated.
- When a pharmacy is chosen as a satellite, its demand is fulfilled by the delivery van. It does not need to be included in the calculation of the bike tours.
- Travel times (bikes and vans): look up on Google Maps. Check addresses in ANNEX 4. Multiply the values (travel times) by 2, because delivery vans and bikes are slower than ordinary vehicles.

ANNEX 4 – Addresses



	Zone	Name	Address
1	A. Tolhuis	Apotheek Erika Lox	Meelstraat2, 9000 Gent
2	A. Tolhuis	COOP - Apotheek - Kathleen Martin	Dobbelslot 2, 9000 Gent
3	A. Tolhuis	Apotheek Tolhuis BVBA	Tolhuislaan 142, 9000 Gent
4	B. Portus Ganda	Apotheek Callebaut BVBA	Clarissenstraat 1, 9000 Gent
5	B. Portus Ganda	Apotheek Brabantdam	Brabantdam 73, 9000 Gent
6	B. Portus Ganda	Apotheek Denys	Kasteellaan 74, 9000 Gent
7	C. Krook	Apotheek Leveugle	F. Rooseveltlaan 505, 9000 Gent
8	C. Krook	Apotheek De Cuyper / Catherine	Nederkouter 123, 9000 Gent
9	C. Krook	Apotheek De Belie NV	Lammerstraat 37, 9000 Gent
10	D. Coupure	Apotheek Cattebeke	Sint-Michielsstraat 15, 9000 Gent
11	D. Coupure	Apotheek Van Der Linden	Annonciadenstraat 21, 9000 Gent
12	D. Coupure	Apotheek Aerts-De Marteleire / M.	Ekkergemstraat 56, 9000 Gent
13	E. Brugse Poort	Apotheek Brugse Poort	Kettingstraat 94, 9000 Gent
14	E. Brugse Poort	Buyse Apotheek NV	Bevrijdingslaan 154, 9000 Gent
15	F. Rabot	Apotheek Rabot	Wondelgemstraat 87, 9000 Gent
16	F. Rabot	Apotheek Spiers	Noordstraat 38,
17	Depot	Apotheek18	Oude-Abdijstraat 100, 9031 Drongen

ANNEX 5 - *Het Circulatieplan*