MGSC 662: Decision Analytics - Fall 2023

Prescriptive Analytics (Optimization) Project

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Important Dates

1. Choose a topic and check with the instructor if the topic is suitable.
2. Submit a project proposal by Thur Nov 2, 11:30 am (maximum one page, one per team) on myCourses.
3. Presentations: Nov 23. Each team has 14 mins to present plus 3 mins to Q&A.
4. Written report: Nov 23 by 11:59 pm through myCourses (one per team).
5. Peer Feedback Form: Nov 24 by 11:59 pm through myCourses (mandatory).

Description: The objective of the project is to apply optimization techniques to interesting and practical problems. The project requires to formulate a problem as an optimization problem, solve it using Gurobi, and interpret the results in the context of the problem. Follow these steps for the course project:

Step 1: Choose a Problem

Meet with your teammates and decide which problem/question you want to study. You are free to choose (Am I? Are you?), but you may wish to speak with the instructor for final approval. I encourage you to work on something that excites you. It would be fantastic if you could tackle a problem you have encountered before in your line of work. This is because you will have the domain knowledge (key decision variables, challenges, likely access to data or where to find relevant data, etc.) which makes the project and the interpretation of its results plausible and interesting. If not, here are some problems you might want to consider.

Sample Problems:

- **Portfolio optimization - Wind Turbine Portfolio of Canada:** Global warming is a reality and most countries have adopted policies to reduce their carbon footprint. For example, Canada has targeted a net-zero carbon economy by 2050. One of the most efficient renewable energy sources is wind. However, producing energy from wind is problematic since wind, as a natural phenomenon, is both uncertain and volatile.[1] The aim of the project is to determine the best location to build wind farms and the optimal size of the farms such that it maximizes the overall average energy production while minimizing the overall volatility of the produced energy. The problem shares a similar structure to portfolio optimization problems. Possible steps:
  - Collect wind data from different locations.
    (Possible source `https://canwea.ca/wind-integration-study/wind-data/`.)
  - Collect wind farm costs and other data.
  - Formulate and solve an optimization problem to decide possible allocations for different budgets.
  - Analyze the solution of the problem as a function of the budget, location options, variability and output of the wind farm.
- **Facility location:** Assume a set of locations (warehouses, recycling facilities, stores, etc.) is given. Assume also that a set of customers should be served from these locations.
  - which facilities should be used and which ones should not.
  - which customers should be served from which facilities so as to minimize the total cost of serving all the customers.

[1] I need to emphasize that wind farms have their own environmental issues. We will discuss one problem briefly related to the recycling of end-of-life-cycle wind turbine blades.

Typically here facilities are regarded as “open” (used to serve at least one customer) or “closed” (not used to serve any customer). There is a fixed cost to keep a facility open. Which facilities to keep open and which ones closed is our decision. This is a classic problem in optimization. It will be interesting to examine how the solution changes when the demand/costs are not known exactly but rather are random outcomes.

An alternative problem is to assume that customer locations are known and the problem is to find the best location(s) for one (or multiple facilities) to serve those customers. This is similar to the wind turbine blades recycling problem I am working on at the moment.

- **Traveling Salesman Problem (TSP) or Vehicle Routing Problem (VRP).** Garbage collection problem in Montreal, School Bus Routing, etc.

- **Scheduling:** The entire class of problems referred to as sequencing, scheduling, and routing are inherently integer programs. Consider, for example, the scheduling of students, faculty, and classrooms in such a way that the number of students who cannot take their first choice of classes is minimized. There are constraints on the number and size of classrooms available at any one time, the availability of faculty members at particular times, and the preferences of the students for particular schedules. You may try and get data from McGill on a program (including the MMA program).

- **Pokemon and more:** Many games like Pokemon can be formulated and solved using mixed-integer optimization. Pokemon combines a few optimization areas such as TSP and generalized TSP. Please note that some of these games are already formulated and solved and can be accessed easily online. I have no objection if you choose to use these sources but the expectation will be higher (clear presentation of the problem including the objective function and constraints and also a clear explanation of the solution approach). You may come across some terminology in these sources that we have not covered in class but if you are using them, you should explain in your presentation (in-class and written).

- **Capacitated Production and Investment planning:** This class of problems combines investment planning problems with network flow problems. Consider the problem of deciding which electricity generator and transmission lines need to be upgraded in order to address the increasing demand in electricity in the near future. This needs to be done at the minimum cost while ensuring that all customer demand is satisfied. The problem can be first formulated as a deterministic problem, and then address the problem under uncertainty.

- **Inventory Control:** Inventory control problems fall within the class of control problems and are used widely in practice. Consider for example a hydro-scheduling problem faced by Hydro Quebec, where they need to decide how much water to use from the reservoir to maximize their profits while ensuring that the water reservoirs do not overflow and cause problems. Other examples include stocking up the warehouse with goods in order to satisfy customer demand. If too many goods are stored in the warehouse, then the operator needs to pay holding cost, while if there are not sufficient goods to satisfy the customer demand, the operator need to pay a backlogging cost.

Step 2: Collect data and formulate the optimization problem

Depending on the problem your group chooses:

- Collect data either from a real application or find data online.
- Find problem instances that will lead to medium-to-large problems, i.e., > 100 variables and constraints.
- Formulate the optimization problem mathematically. Try to formulate it in compact form (recall the formulation of TSP for example and how we showed the constraints in a compact form).

Step 3: Solve the optimization problem

Solve the problem using Gurobi. Code your optimization problem in the software properly and use a suitable optimization algorithm to solve your problem.

Step 4: Interpret the results

It is important to interpret the outcome of the optimization problem. This can be done in many ways. If you are solving linear optimization problems, then one can analyze the shadow prices and interpret the results. If you are solving non-linear optimization problems, you can analyze the structure and limitations of the problem.

Step 5: Examine other research directions

This project is meant to be open ended, i.e., there is no particular target that needs to be achieved. I encourage you to see this project as a research project where the goal is to learn new ways of looking at problems. Discuss what directions the model can take depending on the situation; how can it be enriched, etc.

Presenting your results (Deliverables)

Presentation: This will take place during the final class of the course (Nov 23). You will have 14 minutes. Everyone in the group should contribute to creating the presentation but not everyone is required to do the actual presentation. There must be at least two presenters however. So choose the best ones in the team.

In general, you should target a maximum 14-minute presentation and leave 1-3 minutes for questions. These questions are important for the project evaluation. The entire class is expected to contribute. This would be a good occasion to amass participation points.

Written Report: Type your project (no hand-written report; use ChatGPT for better writing). The length of the report should be 10-12 pages. Exhibits (e.g., extra tables and figures) can add up to additional 10 pages as an appendix. You should submit your code together with your report. If you think it is interesting to show some part of the code in the report, feel free to do so.

Consider using the following framework to organize your paper.

- **Introduction (1 page):** Provide a brief summary of the project, goals, what is interesting about the particular choice of problem, etc.

- **Problem description and formulation (3 page):** You may describe the problem and formulate it mathematically. Depending on the project, you can formulate a basic model first and later provide possible extensions to the model.

- **Numerical implementation and results (4 page):** Here you describe the setting and the data you use to formulate the problem, and discuss how this problem was formulated in the chosen modeling language. You then discuss the solutions that you computed. Does your solution makes sense?! Is the nature of the solution compatible with your understanding of the problem?

- **Problem extensions (2 page):** Here you can discuss possible extensions to the base model and provide numerical results of how the solution changes and the impact on the understanding of the problem.

- **Recommendations and Conclusions (1 page):** Discuss what you would recommend in you were, say, a consultant for that specific project? What have you learned? What would you do differently if you were to do the project again? Were there any bottlenecks in the analysis/numerical experiments that limit the applicability of the method to larger instances?

Grading

Your entire project is worth 25%

- Presentation is worth 12.5%

- Written report is worth 12.5%

REMARK: Your project grade will depend on peer evolutions. You will see your grade for the project but not the grades of your teammates. Peer evaluations are strictly confidential and under no circumstances, they can be discussed or shared with you.