Report of ERO-Montreal

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1 Introduction

As EPITA students, we are tasked with a project to minimize the cost of a typical snowplowing day in Montréal city, which faces significant snowfalls during the winter season. The objective is to reduce the operational costs while providing an efficient snowplow service.

We aim to find the shortest path(s) for a drone aerial check of the road network, identify paths for snowplows to remove snow from the most affected sectors, and propose a cost model for snow removal operations, including the investment in high-performance snowplows.

This report presents a comprehensive analysis of the data provided, the hypotheses and model choices, the proposed solutions and their indicators, and the identified limits of the model(s).

2 Used Data and Studied Perimeter

For this project, we utilized the Python programming language, along with the osmnx and Networkx libraries, to gather and process the data. The osmnx library was particularly useful in downloading and modeling street networks from OpenStreetMap, while Networkx provided us with the necessary tools to analyze and manipulate complex networks.

We focused our study on five sectors of Montréal city: Outremont, Verdun, Anjou, Rivière-des-prairies-pointe-aux-trembles, and Le Plateau-Mont-Royal. This simplification of the task allowed us to manage and process the data more efficiently.

To ensure the accuracy of our data, we filtered out the outgoing roads from our analysis as they are not the responsibility of the city. This step not only ensured that our proposed solutions are applicable and within the city's jurisdiction but also resulted in a strongly connected directed edge, which is crucial for efficient route planning.

The data was then saved in a graphml format, which is a standard XML-based file format for the exchange of graph data. This format was chosen for its compatibility with a wide range of software and its ability to handle large and complex datasets.

3 Hypotheses and Model Choices

In order to develop an effective and efficient solution for the snow removal problem in Montréal city, we made the following hypotheses and model choices:

3.1 Drone Part

We assumed the roads to be undirected for the drone's aerial check. This simplification allowed us to focus on the traversal of the road network rather than the direction of traffic.

We aimed to gather the resulting Eulerian path of the graph. An Eulerian path is a path in a graph that traverses each edge exactly once. This ensured that the drone would check the entire road network without any redundancy.

We focused on the price of the drone per km to reduce the cost of the traversal. This was based on the data provided by the municipality, which included a fixed cost and a cost per km for the drone.

3.2 Snowplow Part

We needed to come up with a way to gather an Eulerian path for the snowplows as well. However, this was trickier due to the direction of traffic and the need to remove snow from both sides of the road.

We decided to split the Eulerian path into smaller sub-paths, each of which could be assigned to a snowplow. This would allow us to parallelize the snow removal process and reduce the overall time.

We focused on reducing the amount of km for the snowplows since the price and the time are highly related to the distance. This was based on the data provided by the municipality, which included a fixed cost, a cost per km, and an hourly cost for the snowplows.

We will vary the amount of fast and basic snowplows to figure out the most optimal situation. The municipality is considering investing in high-performance snowplows, called type II, that can remove snow faster but at a greater cost. By varying the amount of type I and type II snowplows, we can compare the associated costs for different options and make a recommendation for the municipality.

3.3 Summary

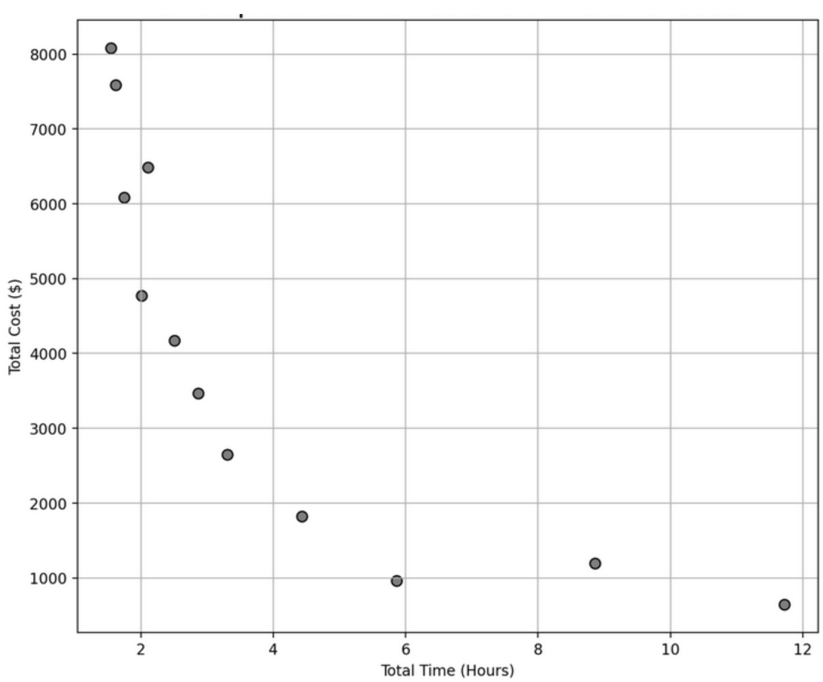
In summary, we made hypotheses and model choices for both the drone and snowplow parts of the problem. For the drone part, we assumed undirected roads, gathered an Eulerian path, and focused on the price per km. For the snowplow part, we decided to split the Eulerian path into smaller sub-paths, each assigned to a snowplow, focused on reducing the amount of km, and varied the amount of type I and type II snowplows to figure out the most optimal situation.

4 Kept Solutions, Indicators, and Comparison between Scenarios

- We split the Eulerian path into smaller sub-paths and assigned each of them to a snowplow. The indicators for this solution were the amount of km and the time spent, both of which we aimed to minimize.
- Regarding the snowplow types, we found that a mix of type I and type II snowplows was the best solution. However, we also found that the Eulerian path split had to be reconsidered to match the difference in speed between the two types of snowplows in the attribution of the road's length.

We also found that there was a threshold on the number of snowplows under which the snowplows might take too long, but the cost was much cheaper. On the other hand, above a certain number, the cost increased very quickly without significantly improving the time spent.

For example, in the Outremont sector, we tested different scenarios with varying numbers and types of snowplow:



5 Identified Limits of the Model

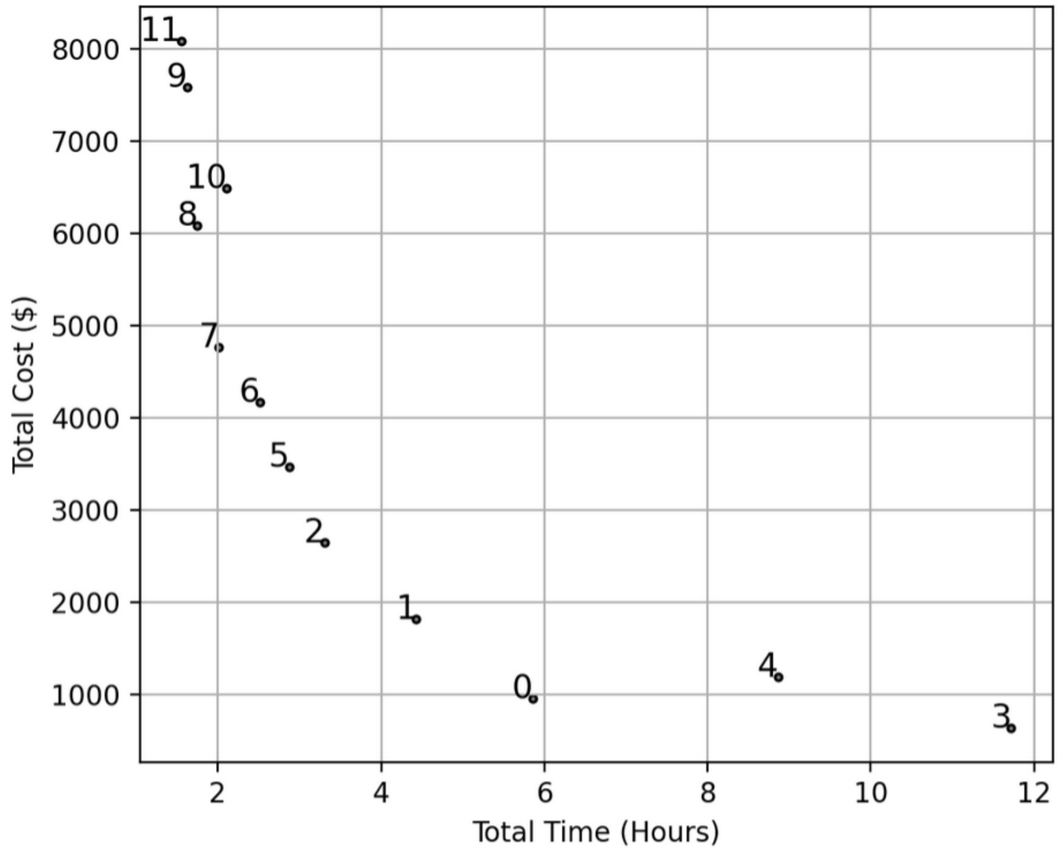
While we believe that our solutions for the snow removal problem in Montréal city are effective and efficient, we also acknowledge that there are some limits to our models:

One of the main limitations of our model is that we do not take into account the constraint of the snowplow buildings. We assume that the snowplows can begin and end anywhere in the city, which might not be the case in reality. This could affect the time and cost of the snow removal operations.

Another limitation of our model is that we do not consider the weather conditions and their impact on the snow removal operations. For example, heavy snowfall or strong winds could slow down the snowplows and increase the time and cost of the operations.

We also do not consider the traffic conditions and their impact on the snow removal operations. For example, rush hour traffic or accidents could delay the snowplows and affect the time and cost of the operations. Additionally, we do not consider the impact of the snow removal operations on the environment. For example, the use of salt and other chemicals to melt the snow could have a negative impact on the water quality and the soil.

6 Annexes



#	Number of Basic	Number of Fast	Total Time	Total Cost
0	0	1	5.86	959.92
1	0	2	4.43	1823.13
2	0	3	3.31	2646.89
3	1	0	11.72	642.5
4	2	0	8.86	1197.97
5	0	4	2.87	3469.44
6	3	3	2.51	4173.81
7	1	5	2.01	4769.58
8	2	6	1.75	6087.66
9	5	6	1.62	7588.34
10	6	4	2.11	6488.14
11	6	6	1.55	8083.6