Postal Transportation Routing Optimization

Fall 2021 MGSC 662 Decision Analytics

Group Project Report

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1 Introduction

Canada Post is a federal Crown corporation that functions as the primary postal operator in Canada. The mission statement is to connect and meet the needs of every Canadian in every community across Canada. The purpose became more significant since 2020 as the country responded to the pandemic. To date, Canada Post has helped deliver to over 16.7 million addresses in various locations across the country.

2020 was a challenging year for Canada Post, which reported a loss before tax of $779 million along with a decrease of $626 million in profitability compared with 2019 due to the increased operational cost related to COVID-19 and a spike of demand in parcel delivery services (Figure 6) [1]. The revenue streams mainly come from its three lines of business: Parcels, Transaction Mail, and Direct Marketing. As reported by the company, Transaction Mail and Direct Marketing lines are expected to continue eroding, while the Parcels line will be the main revenue target strategically for the time being to 2021 or onwards. A significant growth has been seen in the Parcels line, generating over $3.4 billion of revenue in 2020 (Figure 7) [1].

As having the largest retail network with over 6000 retail post offices and a fleet of over 13,000 vehicles, the postal giant is undergoing a mass strategic shift towards digital transformation and optimization [2]. Vehicle routing optimization is part of the agenda. With an increase of 70 million domestic parcels in 2020 and more to come as expected, an increase in delivery-related costs is also within reasonable expectation. These costs which are estimated as variable costs including fuel costs per km and hourly labor costs (Figure 8). They are closely related to the distance of delivery routes.

In this project we would like to focus on only the domestic Parcels line of business within Canada Post since it is the fastest-growing business line and will likely attract more demands going forward due to the increased online shopping trend.

As stated in the company's annual report, piloting dynamic routing is part of the strategic plan for 2021 in terms of technology and digital platform. Therefore, we think that it is interesting to work on this delivery routing optimization problem which minimizes the routing distance and in turn minimizes the total operational cost incurred through fuel usage and labor.

2 Problem Description and Formulation

2.1 Problem Description and Scope

The base problem of this project resembles the parcel delivery business of Canada Post. In this project, we focused on the scenario that a single depot serves a small group of customers in the same region. Multiple vehicles with capacity limit can be used to deliver parcels to the customers. Customers can specify a time window within which the delivery is made. The objective is to minimize the operational cost in order to maximize the profit generated by the parcel delivery service, subject to constraints for customer demands, time, and the vehicle capacity. In this project, only the fuel cost and labor cost were considered as the operational cost. Other costs such as vehicle cost and maintenance cost were not considered given the scope of the project. This optimization model can be formulated into a mixed integer program (MIP) known as Capacitated Vehicle Routing Problem with Time Windows (CVRPTW) which is built upon the classic Traveling Salesman Problem (TSP) that we have learned in class. The model optimizes routes for vehicles with limited capacity to deliver parcels to a given set of customers within the selected time windows to improve delivery efficiency, reduce cost, and maintain customer satisfaction. Additionally, the optimization model also incorporates service time and traveling time needed to fulfill the delivery target. We selected 50 customer locations within the area where postal codes start with H3A and choose the closest Canada Post office to mimic the practical parcel delivery (Figure 1).

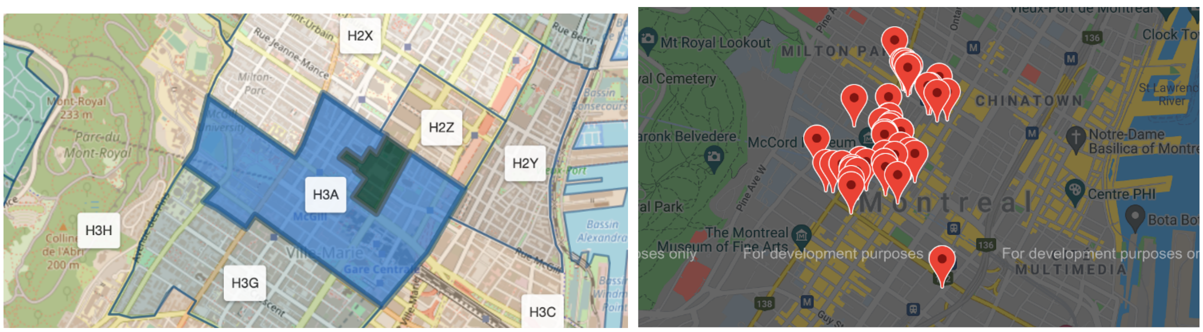

Figure 1: The selected neighborhood and customer locations

Given the size of the project, we further narrowed down our scope by imposing the following assumptions:

- Focus on only one depot and one round of delivery
- All vehicles must depart from and return to the same depot
- All vehicles are homogeneous (same capacity, fuel consumption, etc.)
- Customers do not share location (each location has only one customer)
- Traffic is time-invariant and the same in both directions (symmetric) on the routes
- No limit on the number of vehicles available at the depot
- All customers have specified the time window for delivery
- All possible ending time of time windows are later than all possible starting time

2.2 Parameters

- d_{ij}: the Manhattan distance between location i and j

- q_i: the delivery demand of customer i
- Q: vehicle capacity
- w_i^a: start of time window for customer i
- w_i^b: end of time window for customer i
- s_i: service time for customer i
- t_{ij}: travel time from location i to j
- $\{1, ..., n\}$: a set of customers
- $\{0\}$: depot

Since the location of the customers and depot are provided as geographic coordinates but not Cartesian coordinates, the Manhattan distance between two locations was first calculated using the longitudes and latitudes in the unit of degrees and then converted to the unit of km by multiplying a conversion factor. The delivery demand of each customer and the vehicle capacity are measured by the quantity of parcels only, so they are integers. The start and end of time windows are indicated by time instant in a clock (e.g. 9:00 am, 10:30 am), and the service time and travelling time are measured in hours. The depot has index 0 while the customers are indexed with integers 1 to n, where n is the number of customers to be served.

2.3 Decision Variables

- x_{ij}: whether the vehicle travels from location i to j (arc)
- y_i: cumulative delivery demand that has been delivered after reaching location i
- w_i: service start time for customer i

x_{ij} is a binary variable with the values 0 or 1. $x_{ij} = 1$ if and only if the delivery vehicle travels from customer location i to j directly, and $x_{ij} = 0$ otherwise. y_i is an integral dummy variable that can be interpreted as the cumulative amount of parcels that has been delivered upon location i (including the demand at location i). w_i is a continuous dummy variable that represents the time instant when the mail carrier arrives at location i and deliver the parcels to customer i.

2.4 Base Model Formulation

As stated in the problem description, to minimize the operational cost including fuel cost of labor cost, one might want to minimize the total distance of the delivery routes and the number of carriers (number of vehicles) needed. However, the objective function of our base model only minimizes the total Manhattan distances travelled by all delivery vehicles. We didn't explicitly define the number of vehicles as a decision variable or include it in the objective function because it will be automatically minimized when the model minimizes the distance. The reason is that having more vehicles will always increase the total distance travelled but the model would like to minimize the distance. Therefore, the model will always try to use as the least number of vehicles as possible to satisfy all the customer demand. The minimum number of vehicles needed depends the capacity of the vehicles and the total customer demand. This will be further illustrated in the numerical result section with the result of the base model.

Objective function:

$$min \sum_{i=0}^{n} \sum_{j=0}^{n} d_{ij} x_{ij}$$

subject to constraints:

$$\sum_{i=0}^{n} x_{ij} = 1, j \in \{1, ..., n\} \tag{3.1}$$

$$\sum_{j=0}^{n} x_{ij} = 1, i \in \{1, ..., n\}, \tag{3.2}$$

$$\sum_{i=0}^{n} x_{ii} = 0, i \in \{0, ..., n\}, \tag{3.3}$$

$$y_j \geq y_i + q_j x_{ij} - Q(1 - x_{ij}), i, j \in \{1, ..., n\}, \tag{3.4}$$

$$q_i \leq y_i \leq Q, i \in \{1, ..., n\}, \tag{3.5}$$

$$w_j \geq w_i + (s_i + t_{ij}) x_{ij} - M(1 - x_{ij}), i \in \{0, ..., n\}, j \in \{1, ..., n\} \tag{3.6}$$

$$w_i^a \leq w_i \leq w_i^b, i \in \{0, ..., n\}, \tag{3.7}$$

$$x_{ij} = \{0, 1\}, i, j \in \{0, ...n\}, \tag{3.8}$$

Constraint (3.1) and (3.2) ensure that the vehicles enter and leave each customer location exactly once. Both constraints exclude the depot location by setting different ranges for index i and j. Index j in constraint(3.1) and index i in constraint (3.2) start from 1 instead of 0 as in basic TSP because multiple vehicles can leave or enter the depot (with index 0). Constraint (3.3) prevents self-loops. Constraint (3.4)-(3.7) are for eliminating subtours (i.e. routes that do not pass through the depot) while capturing the business requirements (customer demand and delivery time), which were inspired by Miller-Tucker-Zemlin formulation for TSP. Constraint (3.4) and (3.5) are from the delivery demand perspective. In constraint (3.4), dummy variable y_i represents the cumulative amount of parcels that have been delivered upon location i and if the vehicle goes from location i to j ($x_{ij} = 1$), we add the demand for the next customer j to get y_i which represent the cumulative amount of parcels that have been delivered upon location j. This inequality will always hold when location i and j are not connected by the route ($x_{ij} = 0$) such that no unnecessary constraints are imposed for two unconnected locations. Constraint (3.5) ensure that the cumulative amount of parcels that have been delivered upon each location will always be greater than the demand of any single customer and less than the capacity of the vehicle. Constraint (3.6) follows the same idea as constraint (3.4) but from time perspective. One can think of dummy variable w for carrier arrival time as a cumulative quantity since time always elapses. The total time interval between serving two consecutive customers include the service time needed for the former customer and the travelling time between these two locations. Constraints (3.7) ensures that the carrier arrives at a customer location within the time window specified by that customer. Constraint (3.8) is the binary constraint for decision variable x_{ij}. The numbering of the constraints follows the convention used in the code. There is no special meaning for the numbering.

3 Numerical Implementation and Results

3.1 Data Preparation

The data for customers' locations were obtained from the Open Database of Addresses (ODA) released on April 29, 2021 by Statistics Canada. The database contains addresses and geographic coordinates, which is the useful information we need for our project. We downloaded the dataset for Quebec and saved the address, city, postal code, latitude, and longitude columns only. Since we only focused on 50 customers in downtown Montreal, we selected the data with city as Montreal and postal code starting with H3A, corresponding to the North downtown region where McGill is located. All the data filtering was done in Excel and we output the data as locations.csv. Then, we searched for the closest Canada Post depot on Google Map and obtained its geo information which was then added to the locations.csv file. This file was imported to the Python program and we selected 50 locations for customers and extracted the latitude and longitude columns. Eventually, we created a pandas dataframe containing identity column (depot or customers), the latitude and longitude columns for total 51 locations, which was ready to be used by the program.

3.2 Numerical Parameters

Estimated Parameters:

- Average vehicle travelling speed: $V = 30$ km/h
- Vehicle capacity: $Q = 50$ parcels

Calculated Parameters (with external source):

- Fuel cost per vehicle: C_f =0.15 $/km
- Delivery carrier salary: C_d =18 $/h

- Average Parcel Price: 27.5 \$/Parcel

Simulated Parameters:

- Customer delivery demand: $q_i \in \{1, 2, ..., 8\}$ parcels
- Start of time windows: $w_i^a \in \{9am, 10am, 11am\}$
- End of time windows: $w_i^b \in \{12pm, 13pm, 14pm\}$
- Service time needed for each customer: $s_i \in \{5min, 10min, 15min\}$

We estimated the average vehicle travelling speed based on the typical driving speed in downtown Montreal, and also estimated the vehicle capacity given the size of the vehicle model used by Canada Post and the average parcel size of $1 \times 1 \times 1\text{m}^3$ assuming that the weights are all within limit [3]. The vehicle model used by Canada Post is the Grumman LLV light truck. The average fuel efficiency of Grumman LLV is 15 L/100km in the city [4]. The average fuel price in Quebec in 2020 is 1.01 \$/L [5]. Therefore, the fuel cost was estimated to be 0.15 \$/L (Figure 8). The typical salary for a Canada Post delivery driver is 18 \$/h [6] [7] (Figure 8). The average price for a parcel was estimated by averaging the price rates offered by Canada Post for parcels with different sizes and weights [8]. All the customer related parameters were simulated by Python. Each customer can receive 1 to 8 parcels in each delivery. To simply the model, we simulated the possible ending time of the time windows such that there is no overlap with the starting time of the time windows (all starting time are in the morning, all ending time are in the afternoon). The time in 24-hour clock was translated into floating point numbers in the program, for example, 14:45 was translated into 14.75 h.

3.3 Numerical Results

The optimization model implementation was implemented using Gurobi 9.5 solver in Python 3.8 programming environment. The computer used to test the models has dual core Intel i5 CPU and 8GB RAM. The computing power affects how close we can get to the actual optimal solution. The solution we obtained was near-optimal because the problem is a mixed integer program (MIP) and is NP-hard, which means it is difficult to solve or find an optimal solution. Given the time budget we had for model development and testing, we set the model runtime limit in Gurobi to be 1000s. The model will return the best solution it can find upon the runtime limit. The objective of the base model is to minimize the total distance travelled by the delivery vehicle for serving a particular set of customers, and the minimum total Manhattan distance was found to be 7.73km. Three vehicles are needed to serve this particular set of 50 customers in North downtown Montreal region. The result is reasonable because the total delivery demand simulated by the program is 101 parcels while each vehicle has capacity limit of 50 parcels, so at least three vehicles are needed. It also shows that the number of vehicles needed is minimized by the model. The optimal route for each vehicle is shown in Figure 2 and the visualization of the routes is shown in Figure 3.

```
The optimal delivery route for vehicle 1
0 > 15 > 16 > 18 > 24 > 27 > 26 > 28 > 29 > 25 > 31 > 32 > 33 > 30 > 39 > 38 > 3 > 4 > 21 > 22 > 43 > 45 > 0
The optimal delivery route for vehicle 2
0 > 40 > 49 > 46 > 48 > 47 > 50 > 41 > 0
The optimal delivery route for vehicle 3
0 > 44 > 17 > 19 > 20 > 42 > 2 > 23 > 11 > 6 > 5 > 35 > 34 > 10 > 7 > 8 > 1 > 36 > 9 > 13 > 12 > 37 > 14 > 0
```

Figure 2: Optimization results of delivery routes

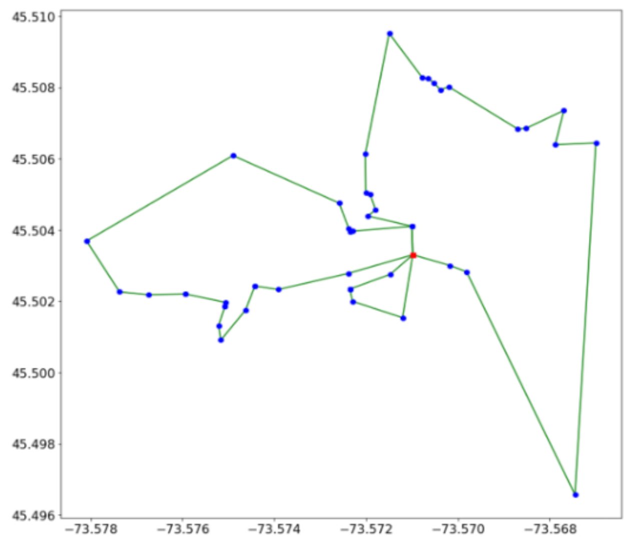

Figure 3: Visualization of delivery routes

We then estimated the revenue and operational cost for serving this particular set of 50 customers with 101 parcels being delivered. The revenue was estimated to be 27.5 $\$/Parcel \times 101 Parcels = \$2777.5$. The operational cost was estimated using the equation (1), where D = 7.73km is the minimum total distance travelled, $C_f = 0.15$ \$/km is the fuel cost, $C_d = 18$ \$/h is the labour cost, $V = 30$ km/h is the average travelling speed of the vehicle, and s_i is the service time needed for each customer. The first term calculates the total fuel costs while the second term calculates the total labor cost (the term in parenthesis is the total mission time). Note that the total distance D and the total mission time are for all three vehicles. The operational cost was estimated to be \$169.2. Therefore, the profit generated by the parcel delivery service with the selected 50 customers will be \$2777.5 – \$169.2 = \$2608.3.

$$\text{Operational cost} = D \times C_f + C_d \times \left(\frac{D}{V} + \sum_{i=1}^{50} s_i \right) \tag{1}$$

4 Problem Extension

4.1 Main Extension

We have discussed how capacity and time windows impact the consideration of Canada Post. Here we will discuss an problem extension that captures more business features. In addition to only delivering parcel to the customers, carriers of Canada Post may also need to fulfill customers' requests for picking up their parcels they want to send. This business scenario can be formulated by a Capacitated Vehicle Routing Problem with Simultaneous Delivery and Pickup and Time Windows (CVRPSDPTW), which is an upgraded version of the base model. All the parcels picked up on the routes need to be carried back to the depot for registration purpose before being distributed to their recipients in the future round of delivery. This requires the vehicles to have some space for on-boarding parcels picked up upon arriving at customers who requested the pick-up service. In this model, we continued to assume that there is only one depot which the vehicles must depart from and return to. The parcels delivered to customers all come from the depot and the goods picked up from customers all head to the depot. This model does not consider the case of direct parcel mailing between customers or any non-depot locations, which means that each vehicle must depart from the depot with only the parcels to be delivered and return to the depot with only the parcels picked up on the routes (delivery has been completed).

Since we incorporated the pick-up service, the formulation of the base model needs to be modified to capture the changes in business scenario. In the extension model, we defined an additional parameter b_i representing the pick-up demand of customer i. For decision variables, we replaced the dummy variable y in the base model with R_{ij} and P_{ij} representing the total amount of parcels for delivery and being picked up respectively on the vehicle on the way from location i to location j. For constraints, we replaced constraints (3.4) and (3.5) in the base model with constraint (4.4)-(4.8) and (4.12 & 4.13). The objective function and all other constraints are the same as in base model.

$$\sum_{i=0}^{n} R_{ij} - q_j = \sum_{i=0}^{n} R_{ji}, j \in \{1, ..., n\} \tag{4.4}$$

$$\sum_{i=0}^{n} P_{ij} + b_j = \sum_{i=0}^{n} P_{ji}, j \in \{1, ..., n\} \tag{4.5}$$

$$\sum_{i=1}^{n} P_{0i} = 0 \tag{4.6}$$

$$\sum_{i=1}^{n} R_{i0} = 0 \tag{4.7}$$

$$R_{ij} + P_{ij} \leq Qx_{ij}, i, j \in \{0, ..., n\} \tag{4.8}$$

$$R_{ij}, P_{ij} \geq 0, i, j \in \{0, ..., n\} \tag{4.12, 4.13}$$

Constraint (4.8) ensure that the sum of pick-up and delivery parcels on the vehicle can not exceed the capacity of the vehicle at any point on the route for each vehicle. Constraints (4.4) states that if a vehicle goes from location i to j, the total amount of deliverable parcels onboard right before arriving at customer j minus the delivery demand of customer j must equal to the total amount of deliverable parcels onboard when the vehicle leaves customer j. Similarly, constraint (4.5) states that the total amount of pick-up parcels onboard right before arriving at customer j plus the pick-up demand of customer j must equal to the total amount of pick-up parcels onboard when the vehicle leaves customer j. Note that constraints (4.4) and (4.5) also serves as subtour elimination constraints. One advantage of this formulation is that it can handle both simultaneous and non-simultaneous delivery and pickup. The non-simultaneous case can be modelled by restricting that one customer can either have pickup demand or delivery demand but not both. Constraint (4.6) and (4.7) ensures that each vehicle must depart from the depot with only the parcels to be delivered and return to the depot with only the parcels picked up on the routes (all delivery has been completed).

We formulated and solved this problem with Gurobi using the same depot and 50 customers as in our base model. The best solution solved within the 1000-second runtime limit gives a total distance of 9.71 km and a total number of 5 vehicles needed for all delivery and pickup demand of the 50 customers. Comparing to result of our base model, two more vehicles are needed and 1.98 km more for the total distance. More vehicles are needed because part of the capacity for each vehicle will be used to accommodate the pick-up parcels, and the total cost increases because of the increase in the total travelling distance. The results are shown in Figure 4 and 5.

```
The optimal delivery route for vehicle 1
0 > 12 > 7 > 6 > 36 > 35 > 11 > 9 > 8 > 2 > 37 > 1 > 10 > 41 > 0
The optimal delivery route for vehicle 2
0 > 15 > 47 > 49 > 48 > 50 > 38 > 14 > 13 > 24 > 39 > 4 > 5 > 0
The optimal delivery route for vehicle 3
0 > 40 > 31 > 34 > 33 > 32 > 26 > 27 > 25 > 28 > 29 > 30 > 0
The optimal delivery route for vehicle 4
0 > 42 > 19 > 17 > 16 > 0
The optimal delivery route for vehicle 5
0 > 45 > 46 > 44 > 22 > 23 > 3 > 43 > 20 > 21 > 18 > 0
```

Figure 4: Optimization results of vehicle routes for problem extension

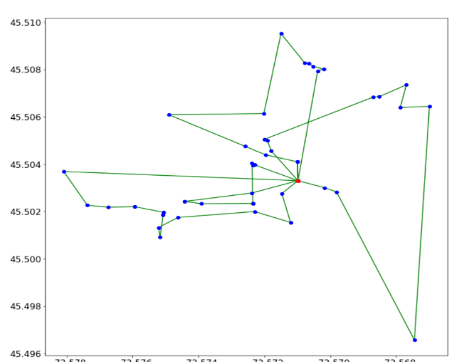

Figure 5: Visualization of vehicle routes for problem extension

Note that in Figure 5, some points and routes are overlapped because some locations are very close to each other and matplotlib cannot handle it well. But the key message is that the routes have changed due to the situation that carriers have to collect pickups from some customers but the vehicle capacity at that time may not be enough. In this case, the pickup and delivery demand of this specific customer must be satisfied by additional vehicles.

The resulting new cost is \$170.78, which increases slightly from the base model. However, the resulting net profit goes up to \$3191.72. Therefore, by adding the pickup service, Canada Post can earn service fees which are a great contribution to Canada Post revenue. Without this formulation, Canada Post may need to deploy additional carriers to handle pickups separately so that the route will be repetitive and Canada Post will be incurred unnecessary distance-related variable costs. More importantly, the vehicle capacity is well leveraged. This formulation is extremely useful because its backhaul and linehaul consideration avoids performing the pickup service separately in another trip. This can in turn affect the freight pricing decision of Canada Post as it can charge less to the demand service for customers at the beginning and pickup service at the end because the carriers have to unload deliveries to be able to load pickups during the first several stops; similarly, during the last several stops, the trucks returning to depot are nearly empty and can load many pickups. Overall, our model can benefit Canada Post in finding the best route for its parcel business, and increase customer satisfaction by considering their time, delivery demand and pickup demand.

4.2 Additional Discussion

The additional discussion was not included in the scope of this project but just an interesting point related to the topic. Consider a realistic scenario on top of the problem extension: if a carrier has to pick up large amount of parcels before deliver the parcels, the pick-up parcels onboarded may obstruct the space at the outer side of the cabin so that the carrier must first unload them in order to take out the parcels to be delivered in the inner side of the cabin. This will create a lot of hassle and spend additional time. One possible strategy proposed by Hoff and Løkketangen [9] for tackling this issue suggests that the carriers deliver some parcels first to reduce the load of the vehicle in order to create a corridor in the cabin for the pick-up parcels to be placed in the inner side of the cabin (see Figure 9 in appendix). At any time on the route, the corridor space is maintained so that both delivery and pick-up tasks can be done at convenience. This idea is also discussed in Wassan and Nagy [10] , named VRP with Restricted Mixing of Deliveries and Pickups (VRPRMDP), which can be achieved by modifying the constraint (4.8) to be:

$$R_{ij} + P_{ij} \leq (1-\gamma)Qx_{ij}, i, j \in \{0, ..., n\}$$

where γ is the percentage of free space. Note that it is sufficient to add this constraint only to the arcs going from a backhaul to a linehaul [11].

5 Conclusion

In this project, we explored several types of vehicle routing problems developed from one of the most interesting topics we learned in class, the TSP, with the application on Canada Post parcel delivery business. Due to the expected size of the project, we made several assumptions that simplify the problem to be manageable as a course project. In reality, the same business problem will be much more complicated where our assumptions will not hold. For example, traffic may be time-dependent in a day and in different seasons. Congestion usually happens during rush hours in the city, and construction is heavy during the summer time, or vehicle traction is reduced on slippery roads in winter. In addition, our models are just for a single depot and a small group of customers. However, Canada Post actually has more than one depot serving many more customers in a certain region with more than one round of delivery. Therefore, our models in this project can serve as a basis for a scaled-up and more sophisticated formulation of a realistic business problem incorporating the factors above and actual business scenarios.

To scale up and be more realistic, the model will become much more complicated with more parameters, variables, and constraints. Thus, there might be challenges or bottlenecks that limit the applicability of the method to larger instances. One challenge would be data collection for those changing factors like real-time traffics. Another challenge would be related to the nature of the problem formulation. In general, a vehicle routing problem can be formulated into a mixed integer program (MIP) which is usually NP-hard. As the problem being scaled up with more variables and constraints, it might take tremendous amount of time for the solver to retrieve a promising result, which means that the route planning cannot be done in a short time. In addition, the result we could obtain is always the near-optimal solution instead of the actual optimal solution. Having found that there are some recently developed algorithms for NP-hard problems which could potentially help with finding the near-optimal solution more efficiently and accurately, a scalable version of the solution to problems with higher complexity is worth exploring to better capture the reality in future works.

Overall, from what we have achieved so far in this project to optimize the delivery routes, it is reasonable to state that the total delivery-related variable costs could be reduced to ultimately increase profits for Canada Post. Therefore, we are hoping that Canada Post would leverage similar or more-in-depth delivery routing optimization models and apply them in a scalable way to navigate through this world of uncertainties.

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A Appendix

Summary of results

(in millions of dollars)	**2020**	2019	Change	%
Revenue from operations	6,942	6,748	194	2.5[1]
Cost of operations	7,740	6,935	805	11.2[1]
Loss from operations	**(798)**	**(187)**	**(611)**	**(326.5)**
Investing and financing income (expense), net	19	34	(15)	(44.4)
Loss before tax	**(779)**	**(153)**	**(626)**	**(409.2)**

Figure 6: Summary of results from 2019 to 2020 [1]

Revenue and volumes by line of business

	Revenue (in millions of dollars)				**Volume** (in millions of pieces)			
	2020	2019	Change	%[1]	**2020**	2019	Change	%[1]
Parcels								
Domestic Parcels	2,681	2,068	613	29.1	292	222	70	30.9
Outbound Parcels	302	243	59	24.2	13	10	3	31.2
Inbound Parcels	432	401	31	7.2	84	88	(4)	(5.0)
Other	19	23	(4)	(17.0)	–	–	–	–
Total Parcels	**3,434**	**2,735**	**699**	**25.0**	**389**	**320**	**69**	**21.0**
Transaction Mail								
Domestic Lettermail	2,335	2,540	(205)	(8.5)	2,432	2,683	(251)	(9.7)
Outbound Letter-post	83	96	(13)	(13.8)	39	45	(6)	(15.2)
Inbound Letter-post	66	78	(12)	(16.2)	69	98	(29)	(29.6)
Total Transaction Mail	**2,484**	**2,714**	**(230)**	**(8.9)**	**2,540**	**2,826**	**(286)**	**(10.5)**
Direct Marketing								
Personalized Mail™	365	485	(120)	(25.1)	648	886	(238)	(27.1)
Neighbourhood Mail™	283	401	(118)	(29.7)	2,474	3,461	(987)	(28.8)
Total Smartmail Marketing™	**648**	**886**	**(238)**	**(27.2)**	**3,122**	**4,347**	**(1,225)**	**(28.5)**
Publications Mail™	129	146	(17)	(12.0)	187	215	(28)	(13.5)
Business Reply Mail™ and Other Mail	19	20	(1)	(5.9)	14	16	(2)	(9.3)
Other	13	14	(1)	0.4	–	–	–	–
Total Direct Marketing	**809**	**1,066**	**(257)**	**(24.3)**	**3,323**	**4,578**	**(1,255)**	**(27.7)**
Other Revenue	215	233	(18)	(8.2)	–	–	–	–
Total	**6,942**	**6,748**	**194**	**2.5**	**6,252**	**7,724**	**(1,472)**	**(19.4)**

Figure 7: Revenue and volumes by line of business from 2019 to 2020 [1]

Costs of Operations - Canada Post Segment	
	2,020
Average Fuel Price of 2020 ($/liter)	1.01
Grumman LLV Fuel Efficiency (liter/100 km)	15
Fuel cost per vehicle per km ($/km)	**0.15**
Delivery driver hourly wage (Payscale)	18
Delivery driver hourly wage (Indeed)	18
Hourly labor cost ($/employee)	**18.00**

Figure 8: Estimated fuel costs and labor costs for 2020 [6] [7] [4] [5]

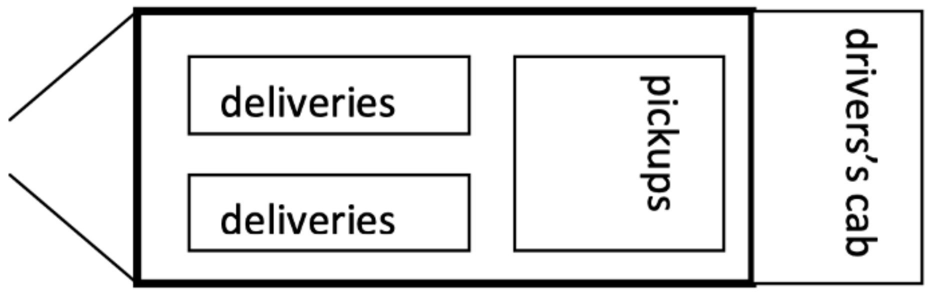

Figure 9: Top view of the room usage in the vehicle [10]