Optimizing the Costs of Keeping Inmates in a Prison Facility

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April 24, 2020

1 Introduction

Canadians pay 9.8 billion dollars for public safety in taxes (Government of Canada, 2015). Incarceration is a part of the public safety sector. Tax dollars pay for running correctional facilities and for keeping an inmate in a facility each day that they are there. Extracting billions for public safety from the public's money may be necessary, but there are areas within public safety where costs can be reduced. This project proves that the cost of transporting prisoners to a correctional facility and the cost of keeping them in that facility can be reduced.

2 Background Data

To construct our optimization problem, we use data from 2016 because more recent data is incomplete or unavailable. Some information for our project was unknown because we cannot find it online; therefore, we use approximations and make educated assumptions about some statistics. However, the Office of the Parliamentary Budget Officer document and Statistics Canada website are useful and are the main sources of our data.

In Figure 1, our supply nodes are locations from British Columbia. This allows us to keep the scale of our project small. We found the two cities in BC with the highest crime rate to be Quesnel and Terrace (Shepert, 2019). We also choose Vancouver and Surrey to be a part of our supply nodes. Next, we found four different security correctional facilities that offenders may be sent to within BC. In this project, we are only considering inmates travelling to a facility directly after sentencing and the costs associated with the inmate staying there after arrival, despite the option of being able to be transferred to another institution. The first facility is a minimum-security prison – Ferndale Institution. The second facility is a medium-security prison – Matsqui Institution. The third facility is a maximum-security prison – Kent Institution. The fourth facility is a healing lodge - Kwìkwèxwelhp Healing Village.

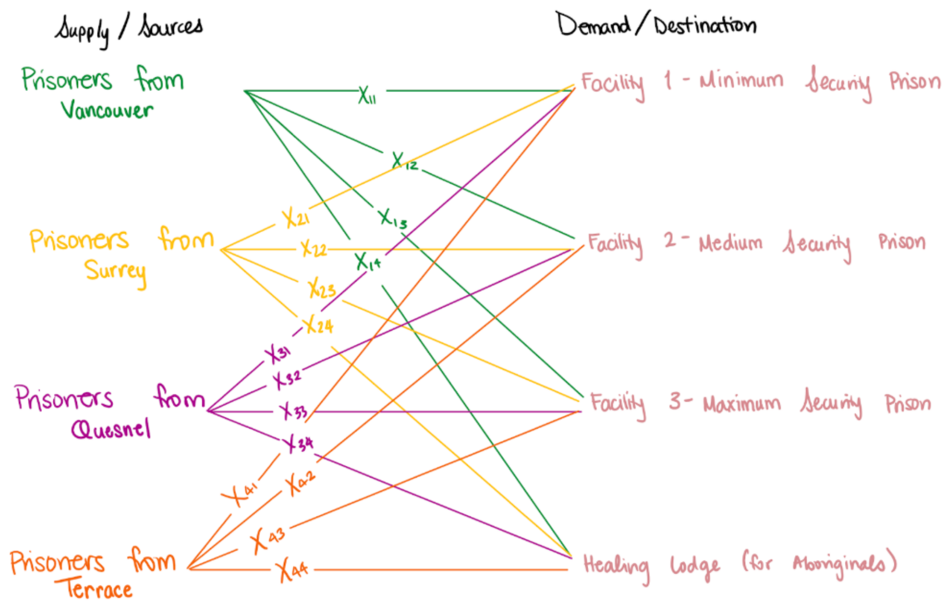

Figure 1: Supply and Demand nodes; Edges x_{ij} represents the number of prisoners leaving a City and entering a Facility

Each facility has a capacity for the number of inmates they can keep, as shown in Table 1. Ferndale Institution has a capacity of 216. Matsqui Institution has a capacity of 446. Kent Institution has a capacity of 378. Kwìkwèxwelhp Healing Village has a capacity of 50.

Capacity of each facility	FERNDALE (Minimum)	MATSQUI (Medium)	KENT (Maximum)	KWÌKWÈXWELHP (Healing Village)
Number of inmates	216	446	378	50

Table 1: Available Space for Inmates in each Facility

Kwìkwèxwelhp Healing Village is an alternate "standalone minimum-security facility that does not conform to any of the traditional complex design features" (Correctional Service Canada, n.d.-c). This facility is focused on Aboriginals and their cultural practices (Correctional Service Canada, n.d.-a). The healing village is also open to non-Aboriginal offenders. A prisoner may also be able to go to the healing lodge after being placed in a different facility.

Our population for our model is 1037 adult male inmates, ages 18 and above. We use adult males because we want to stay with one population to simplify our problem. The offenders in our population of 1037 are also not segregated offenders; we assume they are integrated with the rest of the inmates upon their first correctional facility admission.

To get to 1037 we use the following method. The total number of violations (excluding traffic violations) is per 100,000 people (Statistics Canada, n.d.). We first obtain the total number of violations and divide by 100,000 to get a rate. We then multiply this rate by the population of each city in 2016 - now we have 4 values. Finally, we divide that number by 125 to scale the numbers down. Since we obtain decimal values, we round up to the closest integer because we are dealing with people.

Supply constraints	VANCOUVER	SURREY	QUESNEL	TERRACE
Population	631,486	517,885	23,146	15,723
Crime Rate	51,324.66	44233.23	4298.70	3617.25
Total Supply (decimal)	513.2466	442.3323	42.987	36.1725
Total Supply (rounded up)	514	443	43	37

Table 2: The Total Number of Offenders at each Location

In order to ensure that all facilities receive inmates from all cities, we estimate maximum and minimum bounds for each x_{ij} value. From highest to lowest, the order of population goes in the following order: Vancouver, Surrey, Quesnel, then Terrace. Therefore, the x_{ij} values associated with the higher populations have higher bounds and the values associated with lower populations have lower bounds. Higher Aboriginal populations can be found in Quesnel and Terrace compared to Vancouver and Surrey. This means that we increase the minimum bounds for people going to the healing lodge from Quesnel and Terrace. Moreover, in 2016, 22% of federal inmates were in minimum security, 63% were in medium security, and 15% were in maximum security (Office of the Parliamentary Budget Officer, 2018). We understand that these figures pertain to federal correctional facilities, but this is the most reliable data we can use.

VANCOUVER	SURREY	QUESNEL	TERRACE
$X_{11} \geq 12$	$X_{21} \geq 11$	$X_{31} \geq 10$	$X_{41} \geq 9$
$X_{12} \geq 20$	$X_{22} \geq 17$	$X_{32} \geq 15$	$X_{42} \geq 12$
$X_{13} \geq 9$	$X_{23} \geq 8$	$X_{33} \geq 7$	$X_{43} \geq 6$
$X_{14} \geq 2$	$X_{24} \geq 1$	$X_{34} \geq 3$	$X_{44} \geq 4$

Table 3: The Minimum Bounds ensure that each Facility receives inmates from all cities

Each city is ethnically diverse. According to our research, there are three main categories that inmates fall into: Aboriginal, Caucasian, and other. Provincial and territorial correctional facilities had an Aboriginal population of 28% in 2016 (Statistics Canada, 2018). Originally, we wanted to put all our Aboriginal offenders in the healing lodge; however, before an inmate is sent to a facility, an Aboriginal offender may be sentenced to a higher security prison depending on the nature of the crime. The healing lodge is also not big enough to accommodate all Aboriginal offenders.

The average inmate spends between 30 days to 6 months in prison (Research and Statistics Division, Government of Canada, 2017). The figures in Table 7 are estimations. No facility has a restriction on the period of time an inmate can serve time there, but for the purposes of the project, we pre-determine the average amounts of time spent in each facility. The healing lodge consists of a population of minimum and medium security offenders; therefore, we make the average time spent in the healing lodge the midpoint time between the minimum and medium times.

3 Model

Our goal is to minimize the cost of transporting adult male inmates to a correctional facility in BC.

To model this problem, we use the template of a transportation problem.

3.1 Decision Variables

Since we want to place offenders into each of the facilities, our decision variables are as such:

$$x_{i,j} = \text{number of prisoners going from location } i \text{ to facility } j. \ (\ \forall i, j = 1, 2, 3, 4)$$

Note that i corresponds to the locations that prisoners are coming from and j corresponds to the facility.

3.2 Supply and Demand

Our total supply is equivalent to our total demand, meaning that every offender goes directly from their city to one of the four correctional facilities. We have a total supply of 1037 inmates, thus our total demand must also be equal to 1037 inmates.

We introduce some notation for better clarity:

Supply

$$s_1 = \sum_{j=1}^{4} x_{1j} = \text{number of prisoners from Vancouver}$$

$$s_2 = \sum_{j=1}^{4} x_{2j} = \text{number of prisoners from Surrey}$$

$$s_3 = \sum_{j=1}^{4} x_{3j} = \text{number of prisoners from Quesnel}$$

$$s_4 = \sum_{j=1}^{4} x_{4j} = \text{number of prisoners from Terrace}$$

Demand

$$d_1 = \sum_{i=1}^{4} x_{i1} = \text{number of prisoners in Facility 1 (Min Security)}$$

$$d_2 = \sum_{i=1}^{4} x_{i2} = \text{number of prisoners in Facility 2 (Med Security)}$$

$$d_3 = \sum_{i=1}^{4} x_{i3} = \text{number of prisoners in Facility 3 (Max Security)}$$

$$d_4 = \sum_{i=1}^{4} x_{i4} = \text{number of prisoners in Facility 4 (Healing Lodge)}$$

where s_i is the supply of prisoners from location i and d_j is the demand of facility j.

3.3 Objective Function

Our main objective is to minimize the transportation cost of sending the inmates from Vancouver, Surrey, Quesnel, and Terrace to one of the four facilities. Thus, we let our objective function Z, which is the total cost, to be defined as follows:

$$Min(Z = \sum_{i=1}^{4} \sum_{j=1}^{4} c_{ij} x_{ij})$$

To construct the cost values, c_{ij}, in the objective function, we first calculate the distance from each city to each institution in kilometers using Google Maps, as shown in Table 2.

From Locations	Ferndale Institution	Matsqui Institution	Kent Institution	Kwìkwèxwelhp Healing Village
Vancouver	80.2 km	72.2 km	130.6 km	112.7 km
Surrey	54.8 km	46.8 km	105.2 km	87.4 km
Quesnel	586 km	592.7 km	543.9 km	559.0 km
Terrace	1276 km	1282.7 km	1233.8 km	1249.0 km

Table 4: Distances from location i to facility j (in kilometres) are shown

Then we found the transportation vehicle closest to what we assume inmates would be transported in a bus. We cannot find the exact vehicle that inmates travel in to reach the correctional facility, but we use figures related to a bus because there may be multiple inmates travelling together. To keep our problem simple, we do not take into consideration that there are multiple people on the bus because we do not know how many people are usually transported together to a correctional facility; therefore, we assume one person is on the bus at any time. Next, we find the diesel price in June 2016 because it is the middle of the year – \$1.164 ("Vancouver, BC Average Retail Price," n.d.). The diesel fuel consumption of a bus is 3km per litre.

Thus our c_{ij} was calculated as:

$$c_{ij} = (\text{distances from Table 2 (km)} \times \$1.164) \div 3\text{km/L}$$

Below is a table of all the c_{ij} values.

C_{ij} (cost) values in dollars (\$)	FERNDALE (Minimum)	MATSQUI (Medium)	KENT (Maximum)	KWÌKWÈXWELHP (Healing Village)
VANCOUVER	31.12	28.01	50.68	43.73
SURREY	21.26	18.86	40.82	33.91
QUESNEL	227.37	229.97	211.03	216.89
TERRACE	459.09	497.69	478.71	484.61

Table 5: Cost of Transporting a Prisoner from Location i to Facility j (in dollars).

3.4 Constraints

The following expenditures and information for a correctional facility is from the Office of the Parliamentary Budget Officer (2018) document.

To produce the annual cost per prisoner of the service, we perform the calculations as such:

$$0.09 \times 47370 = 4263.3$$

This provides us with the table below.

Annual cost per prisoner for the expenditure (t_{sj})	Facility 1 Ferndale Minimum	Facility 2 Matsqui Medium	Facility 3 Kent Maximum	Facility 4 Kwìkwèxwelhp Healing Lodge
Utilities, Materials, & Supplies	4263.3	6756.93	8346.6	11,051.64
Amortization of tangible capital assets	3789.60	6006.16	7419.20	9823.68
Professional & Special Services	2842.20	4504.62	5564.40	7367.76
Machinery & Equipment	947.40	1501.54	1854.80	2455.92
Repairs & Maintenance	947.40	1501.54	1854.80	2455.92
Salaries & Employee Benefits	33,159	52,553.90	64,918	85,957.20
Payment in lieu of taxes	947.40	1501.54	1854.80	2455.92
Other Expenses	473.70	750.77	927.40	1227.96

Table 6: Annual Cost per Prisoner of the Service in each Facility

We are only calculating costs for an inmate for the amount of time they will stay in a facility. Table 7 below represents the average time, in days, a prisoner spends in each facility.

Time each prisoner spends in each facility (b_j)	Facility 1 Ferndale Minimum	Facility 2 Matsqui Medium	Facility 3 Kent Maximum	Facility 4 Kwìkwèxwelhp Healing Lodge
Time in days	**30**	**90**	**180**	**60**

Table 7: Average Time Spent by an Inmate in a Facility

These values allow us to calculate the left-hand side (LHS) of our cost constraints. For example, for utilities, materials, and supplies in the minimum security facility we have:

$$((4263.3 \times 30) \div 365) \sum_{j=1}^{4} x_{i1} = 350.41 \sum_{j=1}^{4} x_{i1} = \text{LHS}$$

To compute the right-hand side (RHS) of all our constraints, we first find a base value to compare all other facilities with. To do this, we find the average cost per offender from Summary Table 1 (Office of the Parliamentary Budget Officer, 2018):

$$(47,370 + 75,077 + 92,740 + 122,796) \div 4 = 84,497.75$$

We choose the maximum security facility as our base because the average cost per offender from Summary Table 1 (Office of the Parliamentary Budget Officer, 2018), is closer to the maximum security offender cost, which is \$92,740.

We want to choose our base such that we minimize:

$$d(computed.average, annual.average_j)$$

Where $d(computed.average, annual.average_j)$ is the absolute difference between the $computed.average$ and $annual.average_j$ for facility j. The average annual cost per inmate in facility j is defined by $annual.average_j$, obtained from Summary Table 1 (Office of the Parliamentary Budget Officer, 2018).

Summary Table 1 Estimated cost per offender, 2016-17

Type of Inmate	Annual	Daily
Male Minimum	\$47,370	\$130
Male Medium	\$75,077	\$206
Male Maximum	\$92,740	\$254
Female (all levels)	\$83,861	\$230
Segregation (Incremental)	+\$463,045	+\$1,269
Healing Lodge	\$122,796	\$336
Youth	\$73,632	\$202
Regional Treatment Centre[1]	\$139,128	\$381

Note: Only institution-specific costs are included. Female (all levels) includes minimum, medium and maximum and costs for for each type were not available.

Source: Parliamentary Budget Officer. Model based on historical capacity and number of inmates in segregation provided in CSC Response to PBO IR0305 and expenditures from Public Accounts.

Summary Table 1: This table was taken from Office of the Parliamentary Budget Officer (2018) and contains the annual costs of keeping an inmate in the facility.

We take the four $annual.average_j$'s from Summary Table 1 (Office of the Parliamentary Budget Officer, 2018) and compute $computed.average$ by simple arithmetic:

$$\sum annual.average_j \div n_j = computed.average$$

$$(47,370 + 75,077 + 92,740 + 122,796) \div 4 = 84,497.75$$

where n_j is the total number of j facilities that exist in our problem.

We see that:

$$annual.average_{med} = 75,077 < computed.average = 84.497.75 < annual.average_{max} = 992,740$$

And thus we conclude that:

$$d(computed.average, annual.average_{max} < d(computed.average, annual.average_{med}))$$

We then chose our base to be the maximum facility, $facility_{max}$.

Having a base allows us to compute the RHS of our constraints for the other facilities. Using the values from Summary Table 1 (Office of the Parliamentary Budget Officer, 2018), we calculate the percentage difference between the cost per offender for the different security facilities.

The percentages are calculated using the general formula:

$$annual.average_j \times scale.factor = annual.average_{base}$$

where $annual.average_{base}$ is the annual average of our base obtained from Summary Table 1 (Office of the Parliamentary Budget Officer, 2018), which is $facility_{max}$ in our problem. $scale.factor$ is the decimal form of the percentage difference between operating $facility_j$ and $facility_{max}$.

For example:

$$annual.average_{min} \times scale.factor = annual.average_{max}$$

$$47,370 \times scale.factor = 92,740$$

$$scale.factor = 1.9578$$

This means that on average, $facility_{min}$ costs approximately 95.78% less to operate in comparison to $facility_{max}$. We repeat the same calculations for the other $facility_j$'s to obtain the percentage differences. As a result, we get the percentages 95.78% and 23.53% less for minimum and medium facility, respectively, and 32.41% more for the healing lodge.

Facility 1 Ferndale Minimum	Facility 2 Matsqui Medium	Facility 3 Kent Maximum	Facility 4 Kwìkwèxwelhp Healing Lodge
95.78% Less than base	**23.53%** Less than base	**BASE**	**32.41%** More than base

Table 8: Percentage Difference in comparison to the Base

Now that we have our base and percent differences, we can compute our RHS of our cost constraints.

The Budgetary document used a population of all federal correctional facilities in Canada. There are 53 correctional facilities across Canada. Hence, dividing our annual cost for the expenditure from Table 2-1 (Office of the Parliamentary Budget Officer, 2018) by the 53 facilities gives us our RHS value for the base facility - maximum security. We them divide by the percent difference if the costs are less than the maximum facility, and multiply if the costs are greater than the maximum facility.

Table 2-1 Operating Expenses Associated with Custody, 2016-17

	Total Spending	Average cost per Inmate	% of Total
Salaries and employee benefits	1,102,774,000	78,188.74	70%
Utilities, materials and supplies	136,852,000	9,703.06	9%
Amortization of tangible capital assets	127,889,000	9,067.57	8%
Professional and special services	96,746,000	6,859.47	6%
Payment in lieu of taxes	35,063,000	2,486.03	2%
Machinery and equipment	28,779,000	2,040.48	2%
Repairs and maintenance	27,693,000	1,963.49	2%
All other expenses	17,891,000	1,268.51	1%
Total	$1,573,687,000	$109,971	

Notes: Correctional interventions and internal services are not included. Cost per inmate based on total spending divided by average custodial population (14,310).

Source: Correctional Service of Canada, 2016-2017 Financial Statements, s 16.

Table 2-1: This table was taken from Office of the Parliamentary Budget Officer (2018) and contains the annual costs required for our calculations.

For example, for utilities, materials, and supplies in the minimum security facility, we obtain the RHS by:

$$(136,852,000 \div 53) \div 1.9578 = 1,318,885.08 = \text{RHS}$$

We do these calculations 32 times for each services per facility. Thus resulting in our costs constraints below:

Utilities, Materials, and Supplies

$$350.41x_{i1} \leq 1,318,885.08$$
$$1666.09x_{i2} \leq 2,090,272.17$$
$$4116.13x_{i3} \leq 2,582,113.21$$
$$1816.71x_{i4} \leq 3,418,976.10$$

Professional and special services

$$233.61x_{i1} \leq 932,371.15$$
$$1110.73x_{i2} \leq 1,477,694.67$$
$$2744.09x_{i3} \leq 1,825,396.23$$
$$1211.14x_{i4} \leq 2,417,007.15$$

Amortization of tangible capital assets

$$311.47x_{i1} \leq 1,232,505.87$$
$$1480.97x_{i2} \leq 1,953,371.65$$
$$3658.78x_{i3} \leq 2,413,000.00$$
$$1614.85x_{i4} \leq 3,195,053.30$$

Machinery and equipment

$$77.87x_{i1} \leq 277,352.13$$
$$370.24x_{i2} \leq 439,569.34$$
$$914.70x_{i3} \leq 543,000.00$$
$$403.71x_{i4} \leq 718,986.30$$

Repairs and maintenance

$$77.87x_{i1} \leq 266,886.01$$
$$370.24x_{i2} \leq 422,981.81$$
$$914.70x_{i3} \leq 522,509.43$$
$$403.71x_{i4} \leq 691,854.74$$

Payment in lieu of taxes

$$77.87x_{i1} \leq 312,374.11$$
$$370.24x_{i2} \leq 495,074.91$$
$$914.70x_{i3} \leq 611,566.04$$
$$403.71x_{i4} \leq 809,774.59$$

Salaries and Employee Benefits

$$2725.40x_{i1} \leq 10,627,774.34$$
$$12958.50x_{i2} \leq 16,843,727.52$$
$$32014.36x_{i3} \leq 20,807,056.60$$
$$14129.95x_{i4} \leq 27,550,623.64$$

All other expenses

$$38.93x_{i1} \leq 172,416.00$$
$$185.12x_{i2} \leq 273,258.35$$
$$457.35x_{i3} \leq 337,556.04$$
$$201.86x_{i4} \leq 446,957.95$$

As we have mentioned before, this is a transportation problem and thus we require supply and demand constraints as shown below:

$$s_i = \sum_{j=1}^{4} x_{ij} = \text{number of prisoners from location } i$$
$$d_j = \sum_{i=1}^{4} x_{ij} = \text{number of prisoners in Facility } j$$
$$\sum_{i=1}^{4} s_i = \sum_{j=1}^{4} d_j \text{ (Total Supply equals Total Demand)}$$

We are not allowing any prisoner to be removed from a facility despite the possibility of a conditional release or an acquittal, thus we must also include:

$$x_{ij} \geq 0 \text{ (Non-negativity constraint)}$$

4 Results

Using R, we conclude that our final objective function is a total spending of $57,881 for the year of 2016 for the four facilities we chose with a sample size of 1037 prisoners. This solution is optimal, but it is not realistic because our data set and constraints are composed of estimated values. We cannot compare our results to a real-world optimal solution.

Table 9 on the next page shows our optimal x_{ij} values.

x_{11}	x_{12}	x_{13}	x_{14}	x_{21}	x_{22}	x_{23}	x_{24}	x_{31}	x_{32}	x_{33}	x_{34}	x_{41}	x_{42}	x_{43}	x_{44}
63	402	9	40	127	17	298	1	11	15	12	5	15	12	6	4

Table 9: Optimal x_{ij} values

In an ideal world, our optimal solution is reasonable. We do not obtain negative numbers where we do not expect them.

5 Recommendation

To make our model more realistic, we could alter a variety of the methods that we used in gathering data, and in calculating values for our costs and constraints.

Our optimization problem used data from 2016, effective for a "one-time use" project. This hindered the application and effectiveness of our results. To improve the quality and relevance of our results, we propose that future relevant projects gather a wide range of data from various years. Using a larger data set will allow us to perform a *simple linear regression* (or *multiple linear regression*) and extrapolate those results for practical applications.

Some of the constraints, such as the supply constraints, could be more accurate by using appropriate data sets. Unfortunately, there was a lack of available data for incarceration rates between cities in Canada in 2016. Instead, we used the total law violations (regardless of whether one is sentenced or not), from each city. We calculated a crime rate to generate our x_{1j}, x_{2j}, x_{3j}, and x_{4j} values. If we obtained data more relevant to the incarceration rate in each city, our results will become more accurate.

Some of the methods that we used to calculate different values could be improved using more complex methods. The method we used to calculate our base and *percentage differences* could be modified such that instead of taking $facility_{max}$ to be the base, we could use *computed.average* to be the base and calculate the approximate *percentage differences* of each $facility_j$ where $j = \{min, med, max, HL\}$ to the base. We could use four *percentage differences* as opposed to three. This would make the RHS of our cost constraints more accurate because the RHS would be scaled appropriately according to the *percentage differences.*

Some of the data that we used was made-up using a random-number generator (RNG), despite being under some real-world constraint. This proved to be useful for optimizing our problem but it lacked practicality because it did not represent any real data. We insist that similar future projects do not use randomly generated data. One random generated data set created a *domino effect* by affecting other constraints which led to an inaccurate conclusion. An example of a data set that we used the generator for is the minimum bounds on our demand constraints. Using a RNG caused problems because it is not realistic. Having one prisoner in one facility is not cost-efficient. This could be mitigated if we had a data source that listed the required number of individuals to be held in a facility to keep the facility running.

The *domino effect* led to our next recommendation of finding an exact cost for each cost constraint for each facility (t_{sj}). We calculated these values in our project because there was a lack of available data. We needed to find these values because some of the constraints could be correlated with one another. If we were to have access to a wide range of data from other years, aside from 2016, we could evaluate the *Pearson Correlation* and make educated judgements on how to create more appropriate cost constraints. For example, an increase in "Machinery and Equipment" costs could lead to an increase in "Repairs and Maintenance" costs. By looking at the *Pearson Correlation Coefficient*, we can determine whether this is true or not. If it is true, then we could construct an appropriate linear combination of the two cost constraints such that it restricts our problem effectively. In our model, all our cost constraints were satisfied. This means that the optimization problem would produce equivalent results even if the constraints did not exist. It was a challenge to create linear combinations of the constraints that would further constraint our problem. However, if future projects are able to modify the cost constraints, the results would be more applicable.

Our objective function could also be modified to include the cost constraints to minimize the cost of keeping an inmate in a correctional facility too. Future collaborators should attempt to include these constraints because they are vital in the calculations of overall spending of keeping a prisoner in a facility. We did not include this in our project because the cost constraints were meant to be used as constraints, not part of the objective function. We only wanted to evaluate the costs of transporting prisoners from location i to facility j.

Facility transfers and leaves should also be taken into account. We did not include the possibility of a spot opening for another prisoner if one prisoner leaves facility j. Furthermore, we did not know which vehicle the inmates are being transferred in and how many are usually transported at the same time. We were unsure on how to implement the algorithm for these cases; therefore, we did not include them in our project.

Our project did not include a sensitivity analysis. Future projects based on this model could incorporate a sensitivity analysis to make this a more realistic report. A sensitivity analysis report would allow us to determine which variables are dependant on one another.

Finally, there was very limited data available for the public from reputable online sources. We assumed that this is to protect the privacy of those who have been sentenced to facility j. We could also advance this project if more data sets were available for women and juveniles. To address these limitations, we suggest contacting facility j directly and request data sets to include the average time a prisoner spends in facility j, along with all expenses. This would enable future projects to analyze more accurate data sets. We attempted to contact the facilities ourselves, but none of the facilities got back to us before the project's deadline.

6 Team Member Contributions

Nabila Doctor

My main role in this project was to be the organizer. I made sure to communicate with my team members, via text and Skype, and set time to work on the project together. I even opened a shared Google drive folder for our team to put all our work in. Collectively we gathered information and data on our topic and used it to formulate our model and the constraints. My main contribution was to bring our written- and mathematical-work together and cleaning it up in LaTeX. I did all the formatting and placement of figures and tables into our final documentation, for our submission. Finally, I created a reference page of all the sites we used in our research.

Yumna Parker
My contribution to this project starts with creating the idea of the project. The main concept was to originally reduce the costs of keeping inmates in a facility. However, while we worked on our project, our main goal had to change. I come from a criminology background; so, I sparked the idea of this project from previous knowledge. I helped find sources for the data. I created the tables and figures, except for the ones from the source we used. I wrote the majority of the write-up text. I helped calculate data. I edited most of the write-up notes, including sections that were written by other team members.

Fitz Laddaran
In this project, I was responsible for writing the algorithms associated with optimizing our transportation problem. I have used R to conduct our optimization, which included debugging and using proper coding techniques. Collectively, we also gathered data that we used in our project, and I was responsible for taking the data found and implementing it into R. Furthermore, I implemented the majority of the mathematical methods and algorithms that we used to calculate our "made-up" data. This included figuring out the appropriate bounds of our constraints, and how our constraints should be formulated. Finally, I wrote the "Recommendation" section and description of how we calculated our cost constraints (namely, the base and percentage difference). Lastly, I also helped with editing the submitted document.

7 References

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