Optimisation Individual Report

Contents

Executive Summary

The Warehouse Group Auckland requires a set of routes for their trucks to take in order to ship all their stock to each store, while minimising cost. Factors of this problem include, the length and frequency of the routes, the trucks' capacity to ship stock, and the random variables associated with working alongside traffic. With some assumptions, methods of linear programming and repeated simulation were used in order to determine an appropriate set of routes to take, their associated cost, and the advantages/disadvantages of opening a possible new distribution centre in the north. Introducing this centre was shown to decrease total costs by 33% over the course of an average week. Further work can be done in order to create the most cost-efficient set of routes to take.

Introduction

The problem in which this report and the work leading up to it tried to solve involves the transportation of the daily goods required to ensure the shelves of The Warehouse and Noel Leeming stores are fully stocked every day of the week. In the effort to minimise the cost of this transportation, any combination of routes and trucks, as well as outside contracted help can be used, along with an option of opening a northern distribution centre alongside the already operating southern centre. In theory opening a new node from which trucks can leave from in order to carry out their routes more efficiently should reduce the time and therefore cost of transporting pallets. However, this reduction of cost must outweigh the price of establishing the new centre for it to be viable. Whether the construction of this new centre is viable is one of the main focuses of the overall solution this report finds. Before the end, the recommendations given will show the correct plan of action regarding the routing of the problem, as well as this viability.

Data Analysis and Optimisation

Initial Assumptions

The first task undertaken in the process of creating the model was to come up with sensible assumptions from the problem. These assumptions were later edited to more accurately reflect the situation, and can be found in Appendix A.

Demand Estimates

In developing an appropriate estimate of the number of pallets required per store each day, previously made visualisations of the demand distribution were observed. All stores of each category had a similar average demand during weekdays. Noel Leeming stores had no weekend demand, whereas The Warehouse stores had no demand on Sundays and reduced demand on Saturdays. This evidence was the reason for creating a different set of routes for weekdays and weekends.

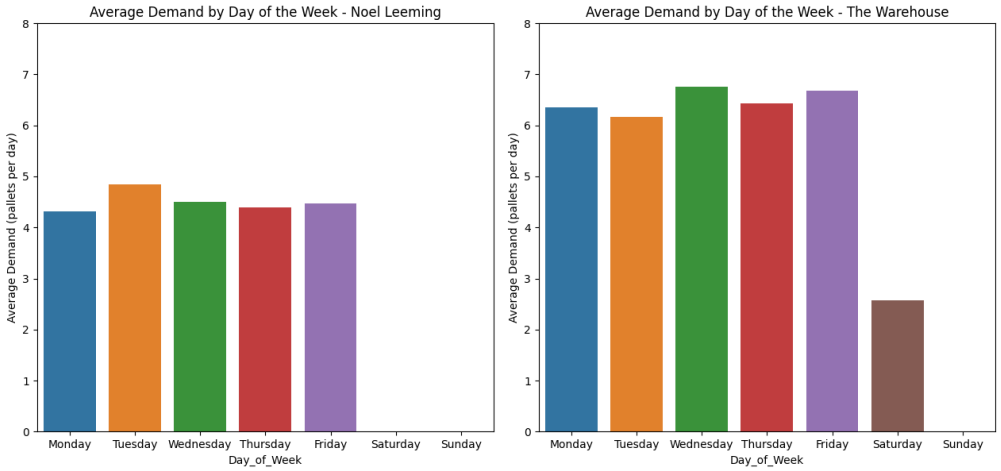

Figure 1: Average demand per day

The visualisations showed that there was no day that caused widespread outliers in terms of demand. The mean weekday demand for each store was taken by averaging its demand for each weekday of the month. The process was then repeated for Saturdays.

Route generation

The generation of routes was done with a linear program. Before this, a set of sections to separate Auckland was decided on in order to make the task more manageable. These were a common-sense collection of stores that take similar general paths from the southern and northern distribution centres[1]. Routes were contained to their own section, hopefully increasing the efficiency of our program. The program maximised the number of stores in a route, with a set of constraints:

- The number of pallets being transported must be less than twenty (the truck's capacity).
- The route must contain a distribution centre. This constraint was changed depending on whether routes were being made for solely the southern centre or both.
- The number of stores visited in the route must be at least two.
- The route must not be the same as a route that has already been created.

Once each route was made, all its permutations were also made and added to the list of routes to be checked against the next route being made. This program was iterated until it became unfeasible, giving us a set of theoretically feasible routes for each of our sections of Auckland[2].

Route Selection

The first step of narrowing down this long list of routes was to find a cost associated with each of them. This was found using a program which iterated through each of the stores in a route, constantly adding the time it takes to drive to and from each, producing a total travel time for that route. The total time spent unloading pallets in a route was also added to this, giving the total time taken by that route. The final cost was determined by adding however much time a route was over four hours, multiplied by the cost per second of going over time, to 700. In simpler terms, the final cost was the sum of the cost of going over time, and the constant cost of a shift of work.

This process was done for every route generated and was how the second linear program was able to select the most optimal ones. The second linear program's aim was, for each section, to minimise the total cost of the routes, while ensuring every store in the section was still visited. With just the constraint that the number of routes could not exceed the number of shifts available (32), the program was successful[3].

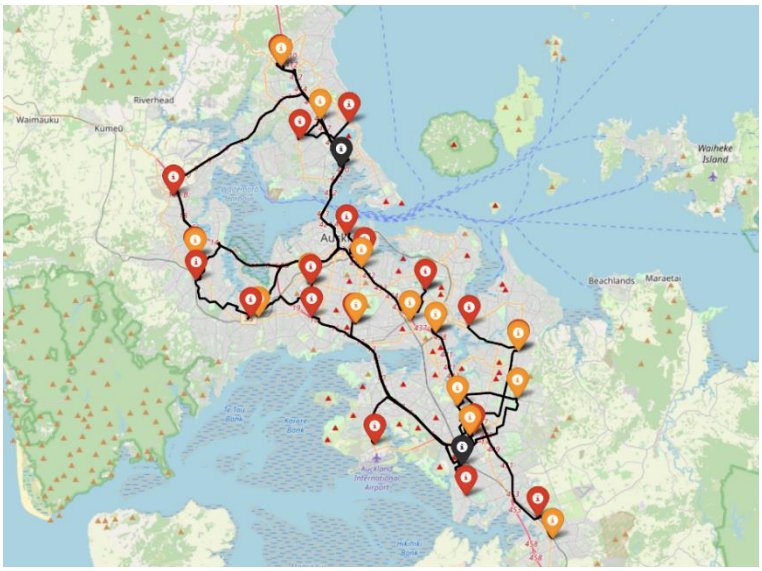

Figure 2: Weekday routes with northern centre

[1] See Appendix B
[2] See Appendix C
[3] See Appendix D for list.

With a set of routes for each section, for with and without the northern distribution centre, an initial hypothesis could be made. If the current routes were taken, with no variance in traffic or demand, adding the northern distribution centre would decrease costs from $57, 485 to $50, 395 per week, a total decrease of $7, 090, or $28, 360 per month. To increase the accuracy of the prediction, simulations were now done.

Simulation Model

Simulation I Formulation

To check the model was able to work in a real-life situation, a simulation was created in order to measure the affect random chance had on the total cost, and the difference between with and without the northern centre. The variables that were to be changed were the demand and traffic.

Initially, a normal distribution of demand variance based on the table of demands given was going to be made, however as it was clear that the demand would only vary from between around two less or two more pallets than the mean, it was decided that the simulation would simply add a random number of pallets between negative two and two to each store's demand for each run.

When beginning to investigate traffic data, some flaws in the modelling became apparent. During the times at which the routes would be driving, the time that it would take to travel between the stores was often much higher than the time given in the initial table, often higher even during the low traffic hours, and sometimes up to three or four times larger during peak hours. These multipliers from the original data were collected from Google Maps, the mean of them being approximately equal to 1.8. The median, standard deviation and skewness were calculated, and a skew normal distribution was created. Random values from this distribution were chosen and multiplied to the travel times of the routes, simulating encountering random traffic while driving.

	RANDOM MULTIPLI
0	4.151426337
1	1.24219485
2	2.459075076
3	2.996196909
4	3.350425492
5	2.455077146
6	3.299217113
7	1.813083959
8	3.91767761
9	3.277831445
10	0.9389532819
11	1.152935384
12	2.448092123
13	1.870855126
14	2.624639848
15	2.358687997
16	2.509293768
17	2.858828886
18	1.268168933

Figure 3: Sample of traffic multipliers

Each route, after being given a new travel time, and number of pallets to deliver, was then iterated through, adding the new total cost each time. Weekdays were run through five times, and Saturdays once in order to produce a weekly cost. This was then run one thousand times, with new multipliers and demands for each route every time, to show a distribution of the most likely weekly costs.

Simulation I Results

Since the routes that were generated were often very close, if not over four hours, the travel time being nearly doubled on average meant that almost all of them went over time, incurring the extra $300 per hour cost, and that made the weekly cost exorbitant. Even with the northern centre, the mean weekly cost of our model was over $400,000.

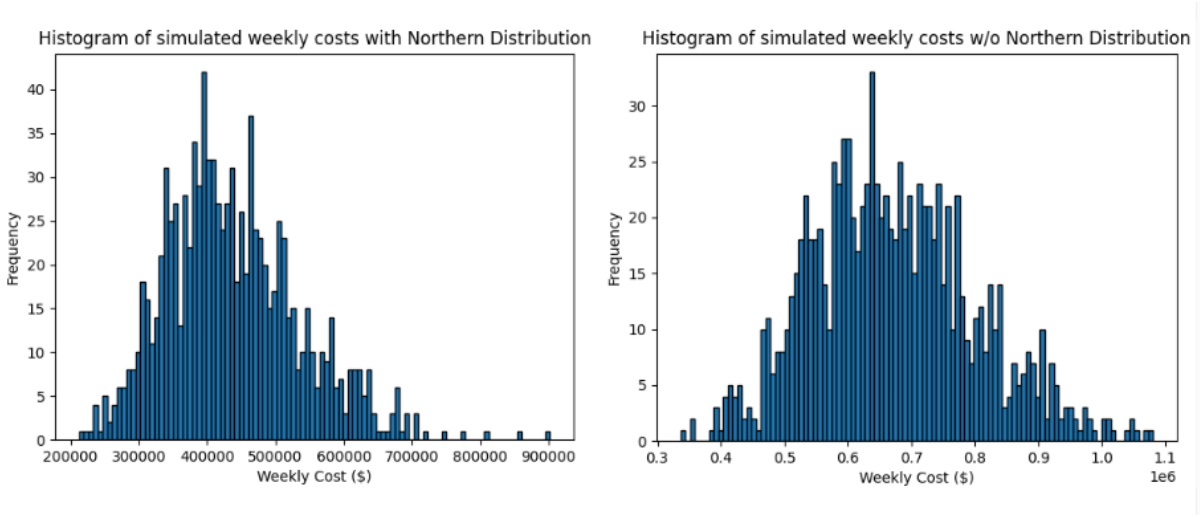

Figure 4: Distributions of Sim I

Although the addition of the northern centre does make a large difference in the weekly cost, the high overall cost means that this was not a very accurate representation of its effectiveness, as well as being a very unaffordable suggestion for routes. After getting these results a new plan was made for a second simulation.

Simulation II Formulation

The main contributor to the high costs of the first simulation was found to be the already long travel time of the original routes. To hopefully fix this issue, new routes had to be created, and selected. In the first linear program, the following constraints were added/revised:

- The maximum number of pallets taken per route was reduced from 20 to 17. Most routes were already under this threshold, however adding this just ensures that there are no incurred Mainfreight costs from being over demand.
- There is a maximum number of stores in a route, four. Most of the routes were already under this, however adding this would greatly reduce the running time of the code, and latter constraints would all but ensure no routes over four stores would be optimal.

Figure 5: New routes with northern centre

These new routes were fed into an edited selection linear program:

- No routes can be over 3.5 hours. This would reduce the extra cost incurred by going over time.
- The extra cost that used to be added past four hours was changed to be past three hours. Although this is not accurate to how the cost is calculated, it encourages the routes to be under three hours, while allowing them to be over if it saves enough cost in total.

After the creation of these new routes[4], they were fed into the same simulation program, with some new more accurate traffic data made in the meanwhile and produced a new set of results.

Simulation II Results

[4] Sample in Appendix E

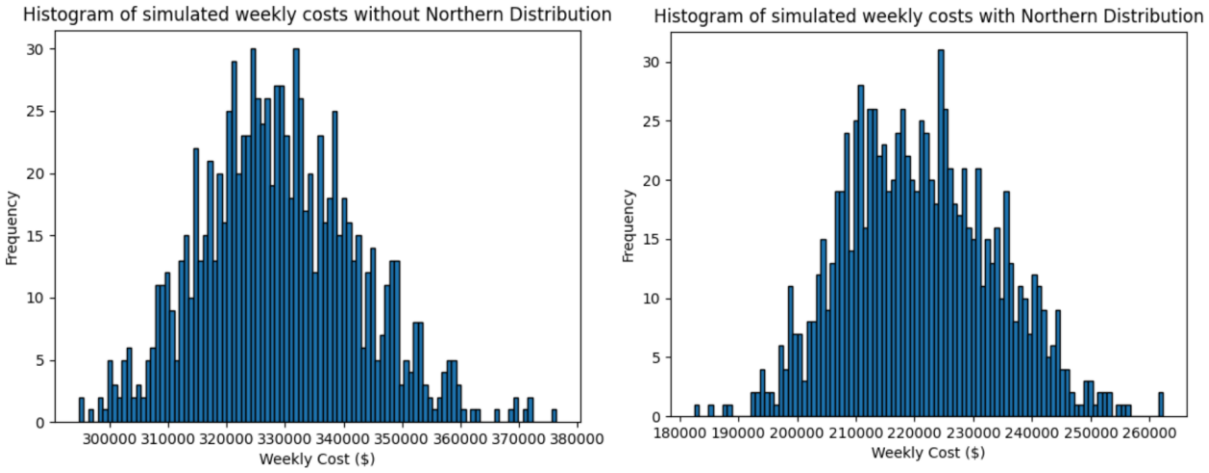

Figure 6: Distribution of Sim II

While still larger than the original estimates of cost, the new simulated weekly costs provided a much more realistic depiction of the routes that should be taken. This concept of manually reducing the travel time of each route, creating more routes could have been taken further if more time was available, as the current ~20 routes provide more than enough breathing room for more to be fit in considering the 32-shift maximum. The 3.5 hour hard constraint to route time may have been able to have been reduced to 3 or even less.

Scenario Analysis/External Impact

Profit Impact

The final simulation gave a clear indication of the impact of adding the northern centre to the system. The mean weekly cost of the simulation without it was $329,000, and with it was $220,000. This is an approximately one third decrease in cost per week, a monthly decrease of $440,000. The addition of the northern centre also decreased the number of routes required to run per weekday from 21 to 18, allowing less trucks and workers to be needed to run them consistently.

Employee Impact

The new set of routes more reliably ensures that driving shifts go over four hours as little as possible. However, with the new centre, routes contain on average two more pallets on weekdays and weekends, meaning that workers will be spending more time unloading (less driving) when compared to before. Switching half of the routes to begin on the other side of the city may also jeopardise the jobs of the drivers currently living in South Auckland. New and old employees must also be instructed to follow the new routing schedule.

Customer Impact

With the northern centre, stock will more reliably be on shelves in time, increasing customer satisfaction and loyalty.

Supplier Impact

The new centre would require suppliers to split their stock to both stores, creating more logistical and transportation costs.

Conclusion

Recommendations and Reflections

Based on the large cost savings indicated by the model and simulations, the recommendations for The Warehouse Group are to open the northern distribution centre. The money saved would outweigh investments of millions of dollars over the course of a just a few years. However, in a real-life situation, it would not be recommended to use the current routes created, as they have the potential to be further optimised, and overall cheaper with more time. A more appropriate set of routes could have been created in time if the issues in the initial assumptions had been spotted earlier, possibly a result of an inexperienced optimisation team. The first formulation of the route selection program inadvertently encouraged fewer and longer routes over brevity and frequency, failing to utilise the total number of trucks at The Warehouse Group's disposal. This program also underestimated the time that a route would realistically take, as the data in which travel time was calculated was much lower than reality. Even so, with a few more tweaks to this route generation a very cost-efficient model could be formed.

That is not to say the current model is not a good solution. It does not meet the standards to be recommended in a professional setting, but it proves that if the project were to continue, it is very much on the right track. What our model does do very well is accurately portraying the high and varied levels of traffic in Auckland during the shift hours, and its implications on the total cost of transportation.

Appendix

A:

- Demand is consistent for each store across days and between weeks. This means that all days across all weeks should have their own, same mean demand. This mean was determined from the demand sample data that was provided.
- Constant traffic flow throughout the day. Initially we used this reasoning to assume that the time taken to travel between stores was equal to the duration dataset given, however later this was changed.
- If the total time a driver would spend working a route is less than 4 hours a whole shift must still be taken. This assumption considers the real-life situation that routes cannot be half finished. For example, a route finishes slightly before 6pm, although there is time left in the shift no other routes can be completed before the shift ends, so the whole shift is spent completing that one route. None of the routes we generated were lower than two hours, eliminating the possibility of multiple routes being fitted into a single shift.
- Since costs are directly related to total time a truck operates our formulations will focus on minimising time, hence minimising the costs. This was a flawed assumption that will be elaborated on later.
- If trip takes over 4 hours, extra shipping costs are calculated continuously, $300 per hour over, $5 per minute. The problem description was not clear on how this cost was calculated, so this assumption was made.

B:

<table>
<tr>
<td>North:
Noel Leeming Albany
Noel Leeming Wairau Park
The Warehouse Albany
The Warehouse Glenfield Mall
The Warehouse Milford</td>
<td>East:
Noel Leeming Ormiston
Noel Leeming Botany
Noel Leeming Sylvia Park
The Warehouse Botany Downs
The Warehouse Pakuranga
The Warehouse Sylvia Park</td>
<td rowspan="2">West:
Noel Leeming Henderson
Noel Leeming New Lynn
Noel Leeming Royal Oak
Noel Leeming St Lukes Mega
The Warehouse Lincoln Road
The Warehouse Mt Roskill
The Warehouse New Lynn
The Warehouse Royal Oak
The Warehouse St Lukes
The Warehouse West City
The Warehouse Westgate</td>
</tr>
<tr>
<td>Central:
Noel Leeming Lunn Avenue
Noel Leeming Newmarket
Noel Leeming Penrose Clearance
The Warehouse Atrium
The Warehouse Lunn Avenue
The Warehouse Newmarket</td>
<td>South:
Noel Leeming Manukau Supa Centre
Noel Leeming Papakura
Noel Leeming Papatoetoe
The Warehouse Airport
The Warehouse Clendon
The Warehouse Manukau
The Warehouse Takanini</td>
</tr>
</table>

C:

WD_NORTH_ALL

	0	1	2	3	4	Route Number	Pallets	Travel Time	Total Time
0	Distribution_North	Distribution_South	Noel_Leeming_Albany	Noel_Leeming_Wairau_Park	The_Warehouse_Milford	0	17	7595.68	17795.68
1	Distribution_North	Distribution_South	Noel_Leeming_Albany	The_Warehouse_Milford	Noel_Leeming_Wairau_Park	1	17	8061.34	18261.34
2	Distribution_North	Distribution_South	Noel_Leeming_Wairau_Park	Noel_Leeming_Albany	The_Warehouse_Milford	2	17	8062.51	18262.510000000002
3	Distribution_North	Distribution_South	Noel_Leeming_Wairau_Park	The_Warehouse_Milford	Noel_Leeming_Albany	3	17	7595.410000000001	17795.41
4	Distribution_North	Distribution_South	The_Warehouse_Milford	Noel_Leeming_Albany	Noel_Leeming_Wairau_Park	4	17	8188.93	18388.93
5	Distribution_North	Distribution_South	The_Warehouse_Milford	Noel_Leeming_Wairau_Park	Noel_Leeming_Albany	5	17	7298.87	17498.87
6	Distribution_North	Noel_Leeming_Albany	Distribution_South	Noel_Leeming_Wairau_Park	The_Warehouse_Milford	6	17	7854.91	18054.91
7	Distribution_North	Noel_Leeming_Albany	Distribution_South	The_Warehouse_Milford	Noel_Leeming_Wairau_Park	7	17	8122.39	18322.39
8	Distribution_North	Noel_Leeming_Albany	Noel_Leeming_Wairau_Park	Distribution_South	The_Warehouse_Milford	8	17	9725.4	19925.4
9	Distribution_North	Noel_Leeming_Albany	Noel_Leeming_Wairau_Park	The_Warehouse_Milford	Distribution_South	9	17	5657.92	15857.92
10	Distribution_North	Noel_Leeming_Albany	The_Warehouse_Milford	Distribution_South	Noel_Leeming_Wairau_Park	10	17	10043.29	20243.29

Sample from data frame of all possible routes for stores in the Northern region on weekdays

D:

	WITHOUT NORTHERN DISTRIBUTION	WITH NORTHERN DISTRIBUTION
North, Weekday	Route 1: 3.76 hours Distribution_South Noel_Leeming_Albany The_Warehouse_Albany Distribution_South Route 2: 3.7 hours Distribution_South Noel_Leeming_Wairau_Park The_Warehouse_Glenfield_Mall Distribution_South Route 3: 2.78 hours Distribution_South The_Warehouse_Milford Distribution_South Two trucks with three shifts = $2100	Route 1: 3.80 hours Distribution_North Noel_Leeming_Wairau_Park The_Warehouse_Glenfield_Mall The_Warehouse_Milford Route 2: 2.52 hours Distribution_North The_Warehouse_Albany Noel_Leeming_Albany One truck with two shifts = $1400
North, Weekend	Route 1: 3.82 hours Distribution_South The_Warehouse_Albany The_Warehouse_Glenfield_Mall The_Warehouse_Milford One truck with one shift = $700	Route 1: 2.58 hours Distribution_North The_Warehouse_Albany The_Warehouse_Glenfield_Mall The_Warehouse_Milford One truck with one shift = $700
East, Weekday	Route 1: 3.88 hours Distribution_South Noel_Leeming_Ormiston The_Warehouse_Sylvia_Park Noel_Leeming_Sylvia_Park Route 2: 4.07 hours Distribution_South Noel_Leeming_Botany The_Warehouse_Botany_Downs The_Warehouse_Pakuranga One truck two shifts = $1400 Extra Cost = $22.11	Route 1: 3.88 hours Distribution_South Noel_Leeming_Ormiston The_Warehouse_Sylvia_Park Noel_Leeming_Sylvia_Park Route 2: 4.07 hours Distribution_South Noel_Leeming_Botany The_Warehouse_Botany_Downs The_Warehouse_Pakuranga One truck two shifts = $1400 Extra Cost = $22.11
East, Weekend	Route 1: 2.44 hours Distribution_South The_Warehouse_Botany_Downs The_Warehouse_Pakuranga The_Warehouse_Sylvia_Park One truck one shift = $700	Route 1: 2.44 hours Distribution_South The_Warehouse_Botany_Downs The_Warehouse_Pakuranga The_Warehouse_Sylvia_Park One truck one shift = $700
Central, Weekday	Route 1: 4.45 hours Distribution_South The_Warehouse_Atrium The_Warehouse_Newmarket Noel_Leeming_Newmarket Route 2: 3.69 hours Distribution_South Noel_Leeming_Lunn_Avenue The_Warehouse_Lunn_Avenue Noel_Leeming_Penrose_Clearance One truck two shifts = $1400 Extra Cost = $135	Route 1: 3.63 hours Distribution_North Noel_Leeming_Penrose_Clearance The_Warehouse_Lunn_Avenue Noel_Leeming_Lunn_Avenue Route 2: 3.91 hours Distribution_North Noel_Leeming_Newmarket The_Warehouse_Newmarket The_Warehouse_Atrium One truck two shifts = $1400
Central, Weekend	Route 1: 2.96 hours Distribution_South The_Warehouse_Atrium The_Warehouse_Newmarket The_Warehouse_Lunn_Avenue One truck one shift = $700	Route 1: 2.59 hours Distribution_North The_Warehouse_Newmarket The_Warehouse_Lunn_Avenue The_Warehouse_Atrium One truck one shift = $700

South, Weekday	Route 1: 3.35 hours Distribution_South The_Warehouse_Manukau Noel_Leeming_Manukau_Supa_Centre Noel_Leeming_Papatoetoe Route 2: 3.10 hours Distribution_South The_Warehouse_Clendon The_Warehouse_Airport Route 3: 2.88 hours Distribution_South The_Warehouse_Takanini Noel_Leeming_Papakura Two trucks three shifts = $2100	Route 1: 3.55 hours Distribution_South The_Warehouse_Manukau Noel_Leeming_Manukau_Supa_Centre Noel_Leeming_Papatoetoe Route 2: 3.10 hours Distribution_South The_Warehouse_Clendon The_Warehouse_Airport Route 3: 2.88 hours Distribution_South The_Warehouse_Takanini Noel_Leeming_Papakura Two trucks three shifts = $2100
South, Weekend	Route 1: 3.40 hours Distribution_South The_Warehouse_Airport The_Warehouse_Manukau The_Warehouse_Takanini The_Warehouse_Clendon One truck one shift = $700	Route 1: 3.40 hours Distribution_South The_Warehouse_Airport The_Warehouse_Manukau The_Warehouse_Takanini The_Warehouse_Clendon One truck one shift = $700
West, Weekday	Route 1: 3.93 hours Distribution_South Noel_Leeming_St_Lukes_Mega The_Warehouse_St_Lukes Noel_Leeming_Royal_Oak Route 2: 3.51 hours Distribution_South The_Warehouse_WestCity Noel_Leeming_Henderson Route 3: 3.17 hours Distribution_South The_Warehouse_New_Lynn Noel_Leeming_New_Lynn Route 4: 3.23 hours Distribution_South The_Warehouse_Royal_Oak The_Warehouse_Mt_Roskill Route 5: 3.91 hours Distribution_South The_Warehouse_Lincoln_Road The_Warehouse_Westgate 3 trucks 5 shifts= $3500	Route 1: 4.08 hours Distribution_South The_Warehouse_Mt_Roskill The_Warehouse_Royal_Oak Noel_Leeming_Royal_Oak Route 2: 4.31 hours Distribution_North Noel_Leeming_Henderson The_Warehouse_Lincoln_Road The_Warehouse_Westgate Route 3: 3.98 hours Distribution_North Noel_Leeming_New_Lynn The_Warehouse_St_Lukes Noel_Leeming_St_Lukes_Mega Route 4: 3.62 hours Distribution_North The_Warehouse_New_Lynn The_Warehouse_WestCity 2 trucks 4 shifts = $2800 Extra time = $117
West, Weekend	Route 1: 3.6 hours Distribution_South The_Warehouse_New_Lynn The_Warehouse_WestCity The_Warehouse_Lincoln_Road The_Warehouse_Westgate Route 2: 2.57 hours Distribution_South The_Warehouse_Mt_Roskill The_Warehouse_St_Lukes The_Warehouse_Royal_Oak One truck 2 shifts = $1400	Route 1: 2.53 hours Distribution_North The_Warehouse_St_Lukes The_Warehouse_Mt_Roskill The_Warehouse_Royal_Oak Route 2: 3.25 hours Distribution_North The_Warehouse_New_Lynn The_Warehouse_WestCity The_Warehouse_Lincoln_Road The_Warehouse_Westgate One truck 2 shifts = $1400
TOTAL	Weekday: $10657.11 * 5 = $53285.55 Weekend: $4200 Total per week: $57485.55	Weekday: $9239.11 * 5 = $46195.55 Weekend: $4200 Total per week: $50395.55

E:

Loc 1	Loc 2	Loc 3	Loc 4
Noel_Leeming_Albany	The_Warehouse_Albany	Distribution_North	Noel_Leeming_Wairau_Park
The_Warehouse_Milford	Distribution_North	The_Warehouse_Glenfield_Mall	0
The_Warehouse_St_Lukes	Distribution_North	Noel_Leeming_Royal_Oak	0
The_Warehouse_Lincoln_Road	Noel_Leeming_Henderson	Distribution_North	0
Distribution_North	Noel_Leeming_St_Lukes_Mega	The_Warehouse_Westgate	0
Distribution_South	The_Warehouse_Mt_Roskill	The_Warehouse_Royal_Oak	0
The_Warehouse_New_Lynn	Noel_Leeming_New_Lynn	Distribution_North	0
The_Warehouse_WestCity	Distribution_North	0	0
The_Warehouse_Atrium	Noel_Leeming_Penrose_Clearance	Distribution_North	0
The_Warehouse_Newmarket	Noel_Leeming_Newmarket	Distribution_North	0
The_Warehouse_Lunn_Avenue	Noel_Leeming_Lunn_Avenue	Distribution_North	0
The_Warehouse_Sylvia_Park	Noel_Leeming_Sylvia_Park	Distribution_North	0
Distribution_South	The_Warehouse_Botany_Downs	Noel_Leeming_Ormiston	0
Noel_Leeming_Botany	The_Warehouse_Pakuranga	Distribution_South	0
The_Warehouse_Airport	Distribution_South	The_Warehouse_Clendon	0
Noel_Leeming_Papakura	Distribution_South	The_Warehouse_Takanini	0
Distribution_South	The_Warehouse_Manukau	Noel_Leeming_Manukau_Supa_Centre	Noel_Leeming_Papatoetoe

Sample from data frame of optimal weekday route for stores in all regions on weekdays