Case Study Assignment Project Brief 2

LogisticsLocal Transport of Diesel to Queensland Towns

Nicklin Creese

26/05/2023

Queensland University of Technology

Introduction to Operations Research

Executive Summary

LogisticsLocal has been contracted to transport fuel from five Queensland ports to ten regional Queensland towns. The ports are Townsville, Abbot Point, Hay Point, Mackay, and Gladstone which currently store 80 kilolitres (kL), 296kL, 1248kL, 112kL and 1280kL, respectively. This fuel needs to be transported to the Queensland towns of Hughenden, Prairie, Muttaburra, Moranbah, Winton, Clermont, Middlemount, Longreach, Emerald, and Blackwater. The ten towns have agreed upon the minimum and maximum amount of fuel they require.

LogisticsLocal employs the use of exclusively 8kL tank trucks, furthermore they can subcontract more truck drivers as required. The truck drivers' wages were found to be equal to 55 cents per 1km traveled in a return trip to port, plus additional loading costs of $300 or $600 are applied if the total distance traveled is greater than 800km or 1600km, respectively.

This report aims to provide recommendations to LogisticsLocal on the trips required from ports to towns to minimize costs while fulfilling contractual obligations. The total cost of subcontracted truck drivers was determined, as well as the average cost of transportation per litre of diesel transported. Furthermore, an analysis was conducted to determine if fuel could be optimally distributed among the ports directly from the supplier to further reduce associated costs.

To provide recommendations to LogisticsLocal, a linear programming transportation model was constructed. The supplied data got manipulated to fit a transportation model. This model was then used to determine the optimal solution to transport the current 3016kL from the five ports to the ten set towns. Table 5 shows the optimal organization of truck transport to minimize truck driver labor costs. This set of return journeys taken results in the total cost of outsourced labor to be $149,914.50. The subcontracted labor costs of the truck drivers cost on average 4.97 cents per litre of diesel transported from the ports to the towns within this contract.

LogisticsLocal wanted to determine if the fuel could be optimally distributed directly from the supplier between the ports to further reduce the total costs of truck drivers. The model removed the constraints defined in table 4 and replaced it with the constraint; the sum of fuel across all ports remains consistent at 3016kL. This unrestricted the initial amount fuel located at each port but kept the total fuel in the system consistent. The model was able to determine the optimum fuel distribution among the five ports was 376kL of diesel at Townsville, 1200kL at Hay Point and 1440kL at Gladstone. The remaining two ports were not used within this solution. This resulted in the labor costs of truck drivers to be reduced to $143,766.10, saving an addition $6,148.40 on the set initial diesel solution. The return trips taken changed from the previous solution to now be equal to the optimal values presented in table 6.

Introduction

LogisticsLocal is a transporting company that has been contracted to transport a total of 3016 kilolitres (kL) of diesel from five Queensland ports to ten Queensland towns. LogisticsLocal has an excess availability of both truck drivers and 8kL tank trucks, all located across the five ports. The supply of the 3016kL of diesel is distributed unevenly across the five Queensland ports namely, Townsville, Abbot Point, Hay Point, Mackay, and Gladstone. The diesel located at these ports currently is 80kL, 296kL, 1248kL, 112kL and 1280kL, respectively.

As per the contract, LogisticsLocal must transport all the diesel located at the ports to ten regional Queensland towns. These towns are Hughenden, Prairie, Muttaburra, Moranbah, Winton, Clermont, Middlemount, Longreach, Emerald, and Blackwater. Each of these towns has submitted a minimum fuel request and a maximum percentage of additional fuel which can be received.

To complete the obligations within the contract, truck drivers are to deliver an 8kL of diesel from a port to a regional town and make a return trip to the port. It has been assumed that truck drivers travel an average of 100km/h. The truck drivers compensated for their work with the following wages. All truck drivers are paid $55 an hour. An additional $300 will be paid to the truck drivers if the return travel distance between a port and regional town exceeds 800km. An additional $300 is paid if the return journey exceeds 1600km, resulting in a total additional payment of $600.

LogisticsLocal is seeking recommendations on the number of trips needed from ports to regional towns to minimize the total cost of the subcontracted truck drivers. They are also interested in knowing the average cost of transportation in cents per litre of transported diesel. LogisticsLocal would like to investigate the effect of fuel potentially being optimally distributed among the five ports prior to distribution to regional towns. They would like to assess if our recommendation is affected if initial fuel at a given port is not set. If so, they would like to know what the optimal distribution of fuel between ports is and quantify the savings because of the optimal fuel distribution.

Methods

To optimize the transportation of diesel from multiple origins to multiple destinations, a linear programing transport model will be employed. This model considers the direct relationship between the source-destination pairs and the total amount of diesel supplied by the ports and received by the towns. To begin the construction of the transport model, let;

Let Z = The total cost of the truck drivers wages (in $).

The objective of the transport model is to determine the minimum values of Z. Let $X_{i,j}$ be definition of the decision variables will be defined as one return trip starting from a port i to a town j and returning. The table below shows the initialization of the decision variables required to determine a solution.

Table 1: The decision variables for return trips made from port i to town j, format $x_{\mathrm{i,j}}$.

	Hughenden	Prairie	Muttaburra	Moranbah	Winton	Clermont	Middlemount	Longreach	Emerald	Blackwater
Townsville	$x_{1,0}$	$x_{1,1}$	$x_{1,2}$	$x_{1,3}$	$x_{1,4}$	$x_{1,5}$	$x_{1,6}$	$x_{1,7}$	$x_{1,8}$	$x_{1,9}$
Abbot Point	$x_{2,0}$	$x_{2,1}$	$x_{2,2}$	$x_{2,3}$	$x_{2,4}$	$x_{2,5}$	$x_{2,6}$	$x_{2,7}$	$x_{2,8}$	$x_{2,9}$
Hay Point	$x_{3,0}$	$x_{3,1}$	$x_{3,2}$	$x_{3,3}$	$x_{3,4}$	$x_{3,5}$	$x_{3,6}$	$x_{3,7}$	$x_{3,8}$	$x_{3,9}$
Mackay	$x_{4,0}$	$x_{4,1}$	$x_{4,2}$	$x_{4,3}$	$x_{4,4}$	$x_{4,5}$	$x_{4,6}$	$x_{4,7}$	$x_{4,8}$	$x_{4,9}$
Gladstone	$x_{5,0}$	$x_{5,1}$	$x_{5,2}$	$x_{5,3}$	$x_{5,4}$	$x_{5,5}$	$x_{5,6}$	$x_{5,7}$	$x_{5,8}$	$x_{5,9}$

The above table 1 shows that Townsville, Abbot Point, Hay Point, Mackay, Gladstone are labeled as ports one to five, respectively. Furthermore, Hughenden Prairie Muttaburra Moranbah Winton Clermont Middlemount Longreach Emerald Blackwater are labelled town one to ten, respectively. Since one return trip carries exactly 8kL of diesel, the supply and demand constraints can be determined. The first constraint is non-negativity for all return trips, for all $i, j, x_{i,j} \geq 0$.

To calculate the acceptable maximum fuel to supply to each town. Firstly, the excess fuel requested was converted from a % of minimum fuel to a set amount in kilolitres. This quantity was then added to the minimum fuel requirements to determine the maximum fuel parameters

Table 2: Converting Excess fuel (%) to maximum fuel values for each regional town.

	Minimum Fuel Requirements	Excess Fuel requested (% of minimum)	Excess Fuel requested(kL)	Maximum fuel to supply
Hughenden	80	30	24	104
Prairie	16	0	0	16
Muttaburra	16	0	0	16
Moranbah	544	50	272	816
Winton	64	25	16	80
Clermont	192	25	48	240
Middlemount	120	20	24	144
Longreach	200	20	40	240
Emerald	920	80	736	1656
Blackwater	280	40	112	392

Looking at table two, it can be easily identified that each town has a corresponding minimum and maximum fuel requirement which must be fulfilled. The below equation describes the total number of journeys from all ports to Hughenden (town 0).

$$\sum_{i=1}^{5} X_{i,0}$$

This can be extended to determine the total amount of fuel (in kL) transported from all ports to Hughenden(town 0).

$$8 * \left(\sum_{i=1}^{5} X_{i,0}\right)$$

This allows the twenty constraints, demand constraints and five supply constraints to be easily defined below within table 3 and table 4.

Table 3: Twenty constraints, Total fuel received must be greater than or equal to minimum fuel requirements but less than or equal to maximum fuel requirements.

	Minimum Fuel Requirements	Total Fuel Received	Maximum fuel to requirements
Hughenden	80	$\leq 8 * \left(\sum_{i=1}^{5} X_{i,0}\right) \leq$	104
Prairie	16	$\leq 8 * \left(\sum_{i=1}^{5} X_{i,1}\right) \leq$	16
Muttaburra	16	$\leq 8 * \left(\sum_{i=1}^{5} X_{i,2}\right) \leq$	16
Moranbah	544	$\leq 8 * \left(\sum_{i=1}^{5} X_{i,3}\right) \leq$	816
Winton	64	$\leq 8 * \left(\sum_{i=1}^{5} X_{i,4}\right) \leq$	80

Clermont	192	$\leq 8 * \left(\sum_{i=1}^{5} X_{i,5}\right) \leq$	240
Middlemount	120	$\leq 8 * \left(\sum_{i=1}^{5} X_{i,6}\right) \leq$	144
Longreach	200	$\leq 8 * \left(\sum_{i=1}^{5} X_{i,7}\right) \leq$	240
Emerald	920	$\leq 8 * \left(\sum_{i=1}^{5} X_{i,8}\right) \leq$	1656
Blackwater	280	$\leq 8 * \left(\sum_{i=1}^{5} X_{i,9}\right) \leq$	392

Table 4: The constraints that restrict the amount of fuel supplied to be equal to the amount of fuel located at each port.

	Minimum Fuel Supplied Restrictions Constraints (in KL)
Hughenden	$8 * \left(\sum_{j=0}^{9} X_{1,j}\right) = 80$
Prairie	$8 * \left(\sum_{j=0}^{9} X_{2,j}\right) = 296$
Muttaburra	$8 * \left(\sum_{j=0}^{9} X_{3,j}\right) = 1248$
Moranbah	$8 * \left(\sum_{j=0}^{9} X_{4,j}\right) = 112$
Winton	$8 * \left(\sum_{j=0}^{9} X_{5,j}\right) = 1280$

To define the objective function Z, the supplied data must be rearranged and manipulated to reflect the expected cost of a return trip from port i to town j. This was completed in excel, the raw one-way travel distance (km) from port i to town j was doubled to get the two-way travel distance. The cost of this journey was then calculated by the formula below:

$$\text{Hourly cost of travel} = \frac{\text{two way travel distance}}{\text{average travel speed}} * \text{hourly wage}$$

$$\text{Hourly cost of travel} = \frac{\text{two way travel distance (km)}}{100\left(\frac{\text{km}}{\text{h}}\right)} * 55\left(\frac{\$}{\text{h}}\right)$$

$$\text{Hourly cost of travel} = \text{two way travel distance (km)} * \frac{\$0.55}{\text{km}}$$

In excel, an IF statement was used to add the extra loading. If $\text{two way travel distance (km)} > 800(km)$ add the additional $300 in loading costs. If $\text{two way travel distance (km)} > 1600(km)$, and the additional $300 in travel costs resulting in a total of $600 of loading costs. The total cost of a return trip from port i to town j ($C_{i,j}$) is the sum of the hourly cost of travel and the additional loading expenses.

The objective function can be identified by the total sum of the decisions variables (amount of trips taken from port i to town j) multiplied by the total cost of a return trip from port i to town j. The objection function was found as seen below;

$$\min_{X_{i,j}\forall i,j} Z = \sum_{j=0}^{9}\sum_{i=1}^{5} X_{i,j} * C_{i,j}$$

This was achieved using SUMPRODUCT function in excel.

Results

Analysis was conducted on LogisticsLocal's transport agreement to minimize the total cost of subcontracted truck drivers. Our recommendation for minimizing the cost of truck drivers can be seen in table 5 below.

Table 5: The total amount of journeys taken for optimum solution with set initial diesel.

Return Journeys Taken	Townsville	Abbot Point	Hay Point	Mackay	Gladstone
Hughenden	8	2	0	0	0
Prairie	2	0	0	0	0
Muttaburra	0	2	0	0	0
Moranbah	0	0	88	14	0
Winton	0	8	0	0	0
Clermont	0	0	30	0	0

Middlemount	0	0	18	0	0
Longreach	0	25	0	0	0
Emerald	0	0	20	0	111
Blackwater	0	0	0	0	49

This assignment of truck drivers to deliver diesel from each port to regional town results in the minimum costs paid to the outsourced truck drivers. The minimum total cost to transport the 3016kL of diesel from the initial ports to the region towns is $149,914.50. This results in the average cost to transport a L of diesel to be 4.97 ¢.

The sensitivity analysis from the set diesel at every port suggests that the lifting of the constraints found in table 4 would affect the initial diesel distribution. This is because each constraint in table 4 (which describes the initial amount on diesel at each port) has a different shadow price. This suggests that differing supplies of diesel at each port will change the total cost of transportation.

To investigate this effect, the transportation model was modified to remove the constraints set in table 4 and one constraint added. This constraint just limits the total amount of fuel to be equal to 3016kL and can be seen below.

$$8(kL) * \left(\sum_{i=1}^{5} \sum_{j=0}^{9} X_{i,j} \right) = 3016(kL)$$

This unset diesel constraint resulted in further reduced transportation costs. This allowed the new optimal solution to have a total cost of $143,766.10. The unset diesel constraint therefore reduced the total cost by $6,148.40 when compared against the set initial diesel solution. To achieve this minimum value, the ideal total fuel supplied from Townsville, Hay Point and Gladstone was 376kL, 1200kL and 1440kL, respectively. It should also be noted, this solution did not require the use of ports located at Abbot Point and Mackey. The return trips taken to achieve this optimum solution with unset initial diesel conditions can be seen in table 6.

Table 6: The total amount of journeys taken for optimum solution with unset initial diesel conditions

Return Trips Taken	Townsville	Abbot Point	Hay Point	Mackay	Gladstone
Hughenden	10	0	0	0	0
Prairie	2	0	0	0	0
Muttaburra	2	0	0	0	0
Moranbah	0	0	102	0	0
Winton	8	0	0	0	0

Clermont	0	0	30	0	0
Middlemount	0	0	18	0	0
Longreach	25	0	0	0	0
Emerald	0	0	0	0	131
Blackwater	0	0	0	0	49
Truck Journeys	47	0	150	0	180

Conclusions

This study aimed to provide recommendations to LogisticsLocal for optimizing transportation planning to fulfill a contract. LogisticsLocal desired a cost-effective transportation schematic to minimize expenses of subcontracted truck driver labor. The contract required 3016 kilolitres of diesel to be relocated from five Queensland ports to ten regional towns.

The results of this study were acquired using a linear programming transportation model. This model calculated the total minimum costs of labor to be $149,914.50 with the diesel set ports. The average associated costs of the transportation of a litre of diesel from a port to a region town is 4.97 cents. The 3016kL of diesel located at the ports of Townsville, Abbot Point, Hay Point, Mackay, and Gladstone, which currently have a supply of 80kL, 296kL, 1248kL, 112kL and 1280kL, respectively. The optimum transportation strategy between ports and towns can be seen in table 5.

Another finding identified was the effect of a modified model with unset initial diesel constraints on the total transportation labor costs. It was found that a further reduction in transportation costs could be achieved with a change in fuel distribution among ports. The optimal fuel distribution from Townsville, Hay Point and Gladstone was found to be 376kL, 1200kL and 1440kL, respectively. This led to total labor costs being reduced to $143,766.10 which leads to a saving of $6,148.40 when compared against the model with set diesel at the ports. The logistics for the alternative optimum solution for unset initial diesel parameters can be seen in table 6. This report provided critical insights into recommendations that will reduce the costs of truck driving labor will fulfilling contractual requirements.