Journal of Sustainable Development of Transport and Logistics
journal home page: https://jsdtl.sciview.net

Jayarathna, N. (2024). Optimizing petroleum redistribution in Sri Lanka: A cost-benefit transportation model. *Journal of Sustainable Development of Transport and Logistics, 9*(1), 121-136. doi:10.14254/jsdtl.2024.9-1.9.

Scientific Platform
ISSN 2520-2979

Optimizing petroleum redistribution in Sri Lanka: A cost-benefit transportation model

Nuwan Jayarathna

Department of Scientific Computing, Faculty of Computing, University of Sri Jayewardenepura, Sri Lanka
nuwand@sjp.ac.lk; nuwan.djsh@gmail.com

OPEN ACCESS

Article history:

Received: February 11, 2024
1st Revision: April 05, 2024
Accepted: May 12, 2024

DOI:
10.14254/jsdtl.2024.9-1.9

Abstract: This case study is based on Ceylon Petroleum Corporation, Sri Lanka, the national oil and gas company and market leader in Sri Lanka. The company's outbound logistics consists of a centralized distribution method and a redistribution process of its products across the island. However, this study mainly focused on one regional depot and one petroleum product, Kotagala depot and Lanka Auto Diesel. The currently centralized redistribution process has noticed extra routing costs due to the unreasonable consumption of additional distance. This problem is modelled as a variant of the vehicle routing problem with a heterogeneous vehicle fleet. Our objective is to minimize the routing costs (or milk-run) by imposing constraints on the capacity and the volume. The researcher introduces a centralized vehicle routing problem that is presented. The proposed vehicle routing problem has been used to find the optimal path between clusters. The computational investigation highlights the cost savings that this new VRP can accrue. Cost savings can be accrued as large as 32.35% compared to a company's existing method.

Keywords: vehicle routing problem, CEYPETCO, petroleum products, redistribution process, centralized redistribution method

1. Introduction

This research is a case study based on Ceylon Petroleum Corporation (CEYPETCO), Sri Lanka's national oil and gas company. It was set up as a state enterprise by Act No. 28 of 1961 in parliament, and further amendments were carried out subsequently, it's a government corporation (established in 1962, 62 years ago). The company's headquarters was located in CEYPETCO House, No. 609, Dr. Danister De Silva Mawatha, Colombo 9, Sri Lanka. 2018 CEYPETCO spread across the island, with an estimated 1278 locations. The company deals with the following products: petroleum, natural gas, motor fuel, aviation fuel, petrochemicals, and lubricate. Moreover, 2,461 employees currently work for the company. The company's principal partner, Ceylon Petroleum, was the Ceylon Electricity Board (CEB).

The demand for Lanka auto diesel is volatile and rising steadily in Sri Lanka. Since these demands have four variables, some variables are social, cultural, seasonal, and environmental. Patterns of demand vary from clauses to provisions. In the Petroleum market, maintaining a high quality of service brings a

Corresponding author: *Nuwan Jayarathna*
E-mail: nuwand@sjp.ac.lk

competitive advantage. A master plan for distribution and redistribution with a decrease in distribution and redistribution costs should be available to sustain the quality of service. The company has outsourced its outbound operation to Ceylon Petroleum Storage and Terminal Ltd. (CPSTL) because CPC is a marketing company and CPSTL performs storage and distribution operations. This study can help CPSTL overcome some challenges in the outbound supply chain.

This study took only one petroleum product and one regional depot from all the petroleum products. They are Lanka Auto Diesel and Kotagala Depot, respectively. The Kotagala regional depot has 16 filling stations to cover. Here, redistribution bowsers are involved in the redistribution operation. The locations of such filling stations are Udupussellawa, Ragala, Kithugala, Nuwaraeliya, Norton Bridge, Pundaluoya, Nanu Oya, Ginigathhena, Maskeliya, Norwood, Talawakele, Hatton, Kotagala.

1.1. CEYPETCO supply chain

Logistics plays the leading role in supply chain management. To be a market leader in the industry, we need final customer attraction, and brands or goods should satisfy customer satisfaction. An intelligent, fast, reliable and interconnected logistics system should be implemented to maintain the above two key aspects. Logistics represents the company's image and generally maintains the service level. To increase service level, there must be a proper current system. CEYPETCO Supply Chain can be divided into two sectors. These are Inbound Logistics and Outbound Logistics. Procurement, including Imports, can be categorized as Inbound Logistics. The procurement department's role is to purchase fuel and raw materials from international suppliers, select suppliers, import fuel, etc. Domestic distribution (for sale) and reverse logistics (collecting empties, sorting empties, and stores) are under Outbound Logistics. Domestic distribution must be high-speed and on-time delivery to maintain the service level.

1.2. Existing company structure

We strive to meet final consumer's demand and supply through our dense and extensive distribution network of over 2 main terminals, 13 regional depots and 1621 dealers and consumers' filling stations across the island.

1.3. Research question

How can we develop and innovate a centralized distribution process to distribute Lanka Auto Diesel using redistribution of vehicles in the Kotagala regional depot with a minimum total transportation cost?

1.4. Description of data

For this research, secondary data from their SAP ERP system. A sales data report for Ceylon Petroleum Corporation was used. Additional required data has been collected from annual reports, such as annual sales, monthly target demand, and chargers for each activity. This research considered one-year daily demand.

1.5. Importance of the research

Redistribution is the most critical process in the outbound supply chain. On the other hand, redistribution shows the company's image and market stability. So, it should be under effective process because it is a critical factor in maintaining service level. Bowser's allocating process is complicated in this field. So, there should be a bowser allocation system that minimizes the cost of transportation while maintaining the maximum service level. Bowser's capacity utilization directly affects the effect on the profit of the business. The total supply chain will break up if the redistribution process becomes critical. Currently, Ceypetco uses centralized distribution strategies in Sri Lanka. However, through research, they can allocate multi-depot distribution strategies, which will help increase service levels while optimizing cost and transportation costs.

On the other hand, having a robust and efficient distribution and redistribution system is a primary competitive advantage of the Petroleum industry. Finding the exact location according to the demand is given the cost-benefit of redistributing petroleum products in Sri Lanka. Applying a master plan for a distribution system in a high-demand area is given cost-benefit and a smooth redistribution route plan.

Through this, Multi depot distribution strategies will help to

- Smooth redistribution root plan
- Cost-optimized redistribution bowser allocation system

The outline of the paper is as follows. Section 1 summarizes the background of the study, the purpose of the study, and related works. Assumptions, notations, problem statements, and model formulation are presented in section 2. Section 3 describes how to use the newly proposed heuristic method, the existing method, and its shortcomings. Further comparative assessments are performed in this section. Finally, the conclusion and recommendation are drawn in section 4.

1.6. Related work

VRP can be explained as the issue of figuring out the lowest cost delivery directions or paths from a depot to a set of geographically dispersed clients, focusing on crosswise limitations. VRP distributes products and services from the supply chain and logistics management backdrop. This is vital for distribution management and should be regularly solved by transporters. Some modifications to the VRP are expressed and grounded, such as the products transporting the service value and the features of clients and vehicles. Dantzig and Ramser (1959) Initially presented "Bowser Dispatching Problem" deals with modelling a fleet of homogeneous bowsers to assist the demand for oil of the number of gas stations from a central hub (Regional Depot) along with the lowest travelling distance. Contributions towards rearranging this issue to a linear advanced optimization problem generally come across in the Supply chain and operational management domain. This can be further explained by how to serve a group of clients, geographically scattered around the regional depot, utilizing the fleet of bowsers with different capacities, becoming VRP amongst the most broadly used phenomena in Advanced Linear Programming.

The enhancement of some forms of VRPs was found together with strategies for calculating the shortest route. Gendreau et al. (2009) defined VRP as a problem of deciding the shortest route from a vehicle that begins from one depot to 'n' several multiple destinations to address various customer needs. Every vehicle with a particular capacity begins at a depot and returns to the main depot, and further, every client can only be toured once. Further, VRP offers a different range of heuristics and metaheuristics approaches, which are introduced in Laporte (2009) and the contributions of (Gendreau et al. (2009) and Chandrasekaran (2010). The VRP is broadly considered because of its familiar use and transportation costs in distribution systems. Therefore, this paper aims to design an approximation of procedures suitable for discovering high-quality solutions in restricted time frames while addressing the real-life problematic circumstances described by huge vehicle fleets and positively to logistics and distribution strategies.

Many public, private, and multinational companies in various industry sectors use contemporary VRP software. Coca-Cola Enterprises is generally significant Drexl (2012). The VRP has increased exponentially at a rate of 6% consistently, which creates a ubiquity in monitoring the expansions in the area and presenting a solid indication of which substitutions and solution approaches are comparatively novel.

Misni and Lee (2017) Introduced a new VRP variant called Capacitated Vehicle Routing Problem with Pick-Up and Alternative Delivery (CVRPPAD) and proposed a hybrid approach to its solution. Misni and Lee (2017) Presented heuristic algorithms for single and multiple depot vehicle routing problems with pick-ups and deliveries. Azi et al. (2010) Introduced a branch-and-price approach to address a vehicle routing problem with time windows and multiple uses of vehicles. Privét et al. (2006) developed a solution approach for Solving VRPTWs with Constraint Programming Based Column Generation. De Silva (2001) Used a Column Generation algorithm to combine Constraint Programming and Linear Programming in a real-world application of Bus driver scheduling. (Laporte, 2009; Misni & Lee, 2017; Nagy & Salhi, 2005) comprehensively reviewed the existing work on the vehicle routing problem with simultaneous pick-up and delivery VRPSPD, especially mathematical formulations, algorithms, variants, case studies, and industrial applications. An overview of existing and emerging vehicle routing problem variants is presented (Arnold et al., 2019; Sitek & Wikarek, 2019; Ganepola et al., 2018) and a local search heuristics approach for solving large-scale routing problems. (Nagy & Salhi 2005; Koç et al. (2021)) proposed three construction heuristics and an improvement procedure for solving a vehicle-routing problem in soft-drink distribution.

Finding the best routes for fleets to reach their customers has been the primary focus of the VRP – Vehicle Routing Problem, which involves calculating the lowest cost delivery directions or paths from a depot to a set of geographically dispersed client's crosswise manner (Jayarathna & Jayawardene 2019; Jayarathna et al. 2019a, b; Jayarathna et al. 2020, 2021a, 2021b,2021c). While most of the literature has focused on inventory control within the warehouse concerning mini-applications of travel plans without having a holistic one, this research is formulated to address the issue of transportation from the warehouse to mini-hubs and from them to the retailers. While others are concerned with plans to address the issues that arise with the expansion of the warehouse, this research focuses on finding an optimum route plan for the distribution of the goods with the hope of introducing a system that could be utilized for most industries in transporting their goods. Privét et al. (2006) Mentioned that petroleum is one of the industries that have a massive impact on the population's living conditions. The petroleum distribution network plays an increasingly important function in delivering value to the end-user. This research aims to study the current petroleum distribution network in Sri Lanka, identify the inefficiencies and causing critical factors, and propose an optimization model to overcome these inefficiencies.

A conceptual framework has been developed based on the findings observed from the critical literature review, and further data was collected from Sri Lankan petroleum industry domain experts using in-depth interviews (Vidal et al., 2020; Yasaman & Joshep, 2015). Optimization is the methodology for improving a product or concept's quality and desirability. Several approaches can be found in the literature, which provides models to coordinate at least two stages of the supply chain and can detect new opportunities that may exist for improving the efficiency of the supply chain and profitability of the organization. Recently, there has been a growing interest in research on supply chain network optimization problems (Rousseau et al., 2004; Gendreau et al., 2002; Daskin et al., 2005), a study that explores the typical petroleum supply chain. A typical petroleum supply chain involves oil exploration, oil production, oil transportation, crude oil storage (tanks are connected to the refinery by a network of pipelines), refinery operations, inventory of the finished products, and distribution (via distribution centers). Strategic, tactical, and operational decision-making is required at all chain stages (Sachini et al., 2019). According to (Sitek & Wikarek, 2019), the petroleum industry has one of the world's most complex and advanced supply chains. It is vertically integrated, covering activities from exploration to transformation in refineries and product distribution with an extensive logistics network. It includes production, transportation, transformation into several refined products, and distribution to consumer markets. The supply chain is divided into upstream, midstream, and downstream Goetschalckx (2011).

2. Assumptions and notation

The underpinning assumptions and notations of the model are as follows:

2.1. Assumptions

(1) Google Maps is used to find the distance between two demand points.
(2) Theoretically, the shortest distance between two points is given by a straight line between the two points. However, since consideration of such shortest distance is impractical, it is not considered here. Instead, we consider only the Google distance value.
(3) Time factors, driver's behaviour, individual condition of the vehicle, unavoidable circumstances like accidents, and weather conditions, which may affect the redistribution process, are not considered.
(4) Distance between outlets in a sub-cluster is not considered.
(5) A rapid change in demand is not allowed.
(6) There is no barrier to delivering petroleum products.
(7) Allocated bowser in a cluster delivers the products within the cluster only. None of the bowsers travel between two distinct clusters.

2.2. Notation

The notation associated with the development of our model is listed as follows:

- **Decision variables**

R = total number of depots arranged in the method;
n_i= number of demand points in the i^{th} depot, $i \in \{1,2,3 \dots \dots . . R\}$;
n = total number of demand points in the distribution;

- **Other parameters**

Parameters for calculate Transportation Cost (Fuel and Maintenance cost)

G = (V, E), a graph of logistics distribution network;
$V = \{V_i / i \in \{1,2,3 \dots \dots . . n\}\}$, set of nodes/vertices;
$E = \{(i, j) \mid i, j \in V, i \neq j\}$, set of arcs in which (i, j) denotes the arc between node i and j;
C_i = number of clusters arranged in i^{th} depot;
n_r^i= number of demand points in r^{th} cluster at i^{th} depot;
$Q_{i,r}$= vehicle capacity of the r^{th} cluster at i^{th} depot ;
q_{jr}^i= weight (demand) associated with the j^{th} client, r^{th} cluster at i^{th} depot;
$d_{V_jV_k}^{ir}$ = distance traveled from client V_j to client V_k in the r^{th} cluster at i^{th} depot;
(Here $d_{V_jV_k}^{ir} = d_{V_kV_j}^{ir}$)
d_{ir} = total distance travelled in the r^{th} cluster at i^{th} depot;
d_i = distance travel in the i^{th} depot vehicle;
d = total distance travel in all depots
VC_{ir} = original vehicle cost for assigning in r^{th} cluster at i^{th} depot;
r_{ir} = annual depreciation ratio for vehicle assigned in r^{th} cluster at i^{th} depot;
t_{ir}= number of years a vehicle is used in r^{th} cluster at i^{th} depot;
R_{ir} = unit distance maintenance cost coefficient ratio for a vehicle used in r^{th} cluster at i^{th} depot;
F_{ir} = unit distance fuel cost coeffcient ratio for a vehicle used in r^{th} cluster at i^{th} depot
AVV_{ir}^t = actual vehicle value which used t years in r^{th} cluster at i^{th} depot;
TC_{ir} = transportation cost for the vehicle in r^{th} cluster at at i^{th} depot;
FC_{ir} = fuel cost for the vehicle in r^{th} cluster at i^{th} depot;
MC_{ir} = maintenance cost for r^{th} cluster at i^{th} depot;
TC_i = transportation cost for i^{th} depot;
TTC = Total Transportation Cost.

2.3. Problem statement and model formulation

- **Problem statement**

This case study is based on Ceylon Petroleum Corporation, Sri Lanka. The company suffers from an extra transportation cost in this system due to covered redundant distances generated by improper utilization of the used Bowsers. So, the company's senior management wants to conduct a further investigation to minimize the additional transportation cost incurred in the current supply chain. The existing distribution network has 2 main terminals, 13 regional depots and 1621 dealers and consumer filling stations across the island. We strive to meet the final consumer's demand and supply, but this study has gone through only in the Kotagala depot and apply for only one petroleum product called Lanka Auto Diesel. LAD is the most in demand for petroleum products in Sri Lanka.

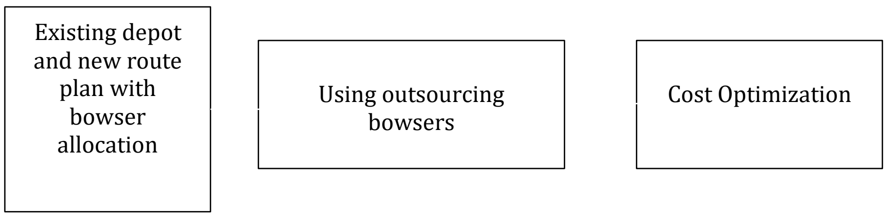
The problem is defined as a completed directed graph G = (V, A), where a tour of each cluster in each depot finishes at the destination node $V_0^i, (V_0^i = V_{n_i,+1}^i)$. We plan to find an optimal number of clusters and depots to minimize the total distance traveled considering all clusters, along with the total number of vehicles and relevant clients for each cluster. Let each depot are ready to provide products for a fleet C_i of vehicles with capacity $Q_{i,r}$ where $i \in \{1,2,3 \dots \dots . . R\}$ and $r \in \{1,2,3 \dots \dots . . C_i\}$. Our intention here is to introduce a method to minimize the total cost of transportation. The nodes excluding the central depots geographically spread customers. Each customer $i \in V - \{V_0^1, V_0^2, V_0^3, \ldots \ldots V_0^R\}$ has certain positive demand such that $\sum_{j=1}^{n_r^i} (q_{jr}^i) \leq Q_{i,r}$. The distance matrix is symmetric, since $d^{ir}_{V_j V_k} = d^{ir}_{V_k V_j}$ for all $j, k \in \{0,1,2,3 \ldots \ldots . . n_r^i\}$, $i \in \{1,2,3 \ldots \ldots . . R\}$,

$r \in \{1,2,3 \ldots \ldots . . C_i\}$,$i \neq j$. The central distribution depots arrange the transportation facilities for the vehicles. That is, the distribution center organizes each vehicle with the transportation plan and the corresponding routing. After fulfilling the requirement, the vehicles start their route from the distribution depot and return to the same depot. This is reasonable as it is common in training that the main distribution depot can alter its vehicles to satisfy the transportation demand. Each vehicle has a load capacity limit and will incur fuel consumption and maintenance while completing its tasks. Thus, a distribution depot has to arrange transportation routing to minimize the total transportation cost of the whole system by taking those costs into account.

A research gap exists between the existing VRP's and our proposed new model in this paper. Our proposed model is new in that we include the transportation cost incurred in the Kotagala regional depot, which is essential to transportation practice in the new perspective of coordinating the economic cost. The solution to the model consists of designing optimal delivery routes: (1) starting and ending at the Depots, (2) visiting each filling station exactly once, (3) satisfaction with all demands. Total cost is equal to the sum of transportation costs.

This research is based on the existing centralized distribution Strategy for the Kotagala regional depot and proposes a new route plan allocation distribution strategy. Figure 1 below shows the Conceptual framework.

Figure 1: Conceptual framework



2.4. The model formulation

This section considers a transportation system of petroleum products from a depot using a group of vehicles. The distribution depots organize each vehicle with a transportation plan along with routing. A vehicle starts its route from the distribution depot and returns to the same after fulfilling the requirement. Assume that the number of vehicles for the task is large enough to satisfy all the transportation demands. This is a reasonable assumption as it is common in training that the main distribution depot can alter its vehicles to satisfy the transportation demand. Each vehicle has a load capacity limit and will incur fuel consumption and usage costs while completing its tasks. Thus, the central depot has to arrange transportation routing to minimize the total transportation cost of the whole system by taking those costs into account. Thus, in comparison with the existing VRP models, our proposed model in this paper is new in that we include the fuel consumption and usage costs, which are essential to the transportation practice in the perspective of coordinating the economic cost. Here, the fuel consumption cost mainly comprises the oil and usage costs.

- **Introduce cluster analysis vehicle routing method**

Researchers have developed a heuristic method to solve the time-dependent vehicle routing problem. First, we form the clusters of clients based on each client's vehicle capacity and demand. Then, the optimal number of clusters along with relevant clients is found following this heuristic; finally, the total transportation cost is calculated by summing up the transportation cost of each sub-cluster. The algorithms for the heuristic methods are given below.

- **Model formulation for calculating fuel and maintenance cost of transportation**

$ALL_{ir}^{t} = VC_{ir} - (r_{ir})^{t} VC_{ir}$, vehicle value which used t years in r[th] cluster vehicle at i[th] depot;

$FC_{ir}=AVV_{ir}^{t} * R_{ir} \sum_{j=0, j \neq k}^{n_i} \min(d_{V_j V_k}^{ir})$, where $j, k \in \{0,1,2,3 \dots\dots n_i\}$

$MC_{ir}=AVV_{ir}^{t} * F_{ir} \sum_{j=0, j \neq k}^{n_i} \min(d_{V_j V_k}^{ir})$, where $j, k \in \{0,1,2,3 \dots\dots n_i\}$

respectively.

$TC_{ir} = FC_{ir} + MC_{ir}$

$TCT_i = \sum_{r=1}^{C_i} TC_{ir}$, Hence the total cost over the clusters, along with the constraints, can be formulated as

$$TTC = \sum_{i=1}^{R} \sum_{r=1}^{C_i} [AVV_{ir}^{t}] * [R_{ir} + F_{ir}] \sum_{j=0, j \neq k}^{n_r^i} \min(d_{V_j V_k}^{ir}), \quad (1)$$

$$d_{ir} = \sum_{j=0, j \neq k}^{n_r^i} \min(d_{V_j V_k}^{ir})$$

$$d_i = \sum_{i=1}^{R} (d_{ir}), \quad (2)$$

$$\sum_{j=1}^{n_r^i} (q_j^{ir}) \leq Q_{i,r} \quad (3)$$

Constraint (3) ensures that the total demand arises in the r[th] cluster vehicle at i[th] the depot cannot exceed the vehicle capacity.

$$n_i = \sum_{r=1}^{C_i} (n_r^i) \quad (4)$$

$$n = \sum_{i=1}^{R} (n_i) \quad (5)$$

$$n = \sum_{i=1}^{R} \sum_{r=1}^{C_i} n_r^i, \quad (6)$$

$$d_{V_j V_k}^{ir} + d_{V_k V_l}^{ir} \geq d_{V_j V_l}^{ir} \text{ for all } j, k, l \in \{0,1,2,3 \dots\dots n_i\} \quad (7)$$

$$d_{V_j V_k}^{ir} = d_{V_k V_j}^{ir} \text{ for all } j, k \in \{0,1,2,3 \dots\dots n_r^i\}, i \in \{1,2,3 \dots\dots R\}, i \neq j \quad (8)$$

To serve the customers, we have to design routes for a fleet with C_i vehicles distributed from i[th] depot, where, $i \in \{1,2,3 \dots\dots R\}$. Each route must start at the depot, visit a subset of customers and then return to the depot. All customers must be visited exactly once. This model is developed for multi-depot systems but can be used for the single-depot to calculate all costs.

Finding an optimal solution to this model is a comprehensive task requiring much calculation time (Arnold, Gendreau & Sorensen, 2019). However, this model has economic value and is mainly associated with integrated supply chain management. As a result, many logistics solution providers have emerged to cater to this rising demand, and companies are highly paying for these custom-made solutions. Excel software has also been developed to facilitate accurate solutions to these mathematical models.

The solution can be obtained faster and without errors by coding the objective function and all the constraints in a particular programming language.

3. Analysis of the research

3.1. Descriptive analysis

Here, we provide the current existing approach arranged by Ceylon Petroleum Corporation to analyze the transportation cost for a particular distribution of consumers, which requires clustering customers. The company adopted a centralized distribution system to cover the demand for 16 filling stations through one regional depot in Kotagala. According to the monthly sales volume obtained by the Ceypetco database system (SAP), 68298 units (volume in Liters) will be redistributed throughout the Kotagala regional depot transport system.

Table 1 shows the annual and monthly sales data of Kotagala depot in 2019 figures.

Table 1: Annual and average daily sales of Sri Lanka

Distribution Centre (Kotagala Regional Depot)	Annual Demand Quantity (units)	Demand Quantity Per Day (units)
D & T	1,075,800	3,201.79
NAWA MPCS LTD	1,148,400	3,417.86
HIRUN	2,527,800	7,523.21
D.D. KASTHURI	6,230,400	18,542.86
K.A. JOTHIPALA	237,600	707.14
PUNDALU OYA	831,600	2,475.00
M.H. SARATH	930,600	2,769.64
GINIGATHENA	1,221,000	3,633.93
MASKELIYA	1,366,200	4,066.07
MASKELIYA	613,800	1,826.79
U.K. BUDDHA	1,986,600	5,912.50
MS.M.Y. HEMA	79,200	235.71
OKMART	1,735,800	5,166.07
R A D J RANA	805,200	2,396.43
M UDAYA	270,600	805.36
M.WEERASIN	1,887,600	5,617.86
Total	**22,948,200**	**68,298.21**

3.2. Route allocation and bowser allocation model

The researcher measured the distance between each demand point in the distribution and the existing regional depot location. It helps to find the optimum route plan for each demand point in the distribution. Through the methodology of this research, early introduced a new heuristic method to arrange clusters for all demand points. Because the capacity of the proposed vehicle exceeds the total daily demand of the route, it is directed to reduce the number of vehicles for relevant routes. If the total demand is too small compared to the proposed vehicle capacity, they should consider reducing cost by arranging another vehicle with a capacity near the total demand of the relevant route. If the total demands of the relevant route exceed the vehicle capacity, the company should find the optimal number of vehicles and the route plan for each vehicle.

3.3. Introduce the proposed Algorithm for cluster analysis on a depot with multiple demand points

- **Cluster Analysis Based on Kotagala depot**

Table 2 shows the starting and ending town of each of the sub-tours of cluster 1 relevant to Kotagala Depot, along with optimal distances travelled (Google distance) and the total distance traveled inside cluster 1 (total milk run).

Table 2: Starting and ending nodes of cluster 01- Kotagala depot

Starting node	Ending node	Distance Travel	Average Daily Demand: Volume in Liters	Remain Diesel
KOTAGLA DEPOT	MS.M.Y. HEMA	13	235.71	32764.29
MS.M.Y. HEMA	M.H. SARATH	14.6	2769.6	29994.65
M.H. SARATH	D.D. KASTHURI	9.5	18543	11451.79
D.D. KASTHURI	NAWA MPCS LTD	23	3417.9	8033.93
NAWA MPCS LTD	D & T ORG	15	3201.8	4832.14
D & T ORG	KOTAGLA DEPOT	68.2	0	4832.14
Total distance Traveled inside the cluster 1			**143.3**	**km**
Total Volume within-cluster (Volume in Liters)			**28168**	**liters**

The optimal path of cluster 1- (Kotagala Depot) is shown in Figure 2.

Figure 2: Optimal path of Cluster 01- Kotagala depot

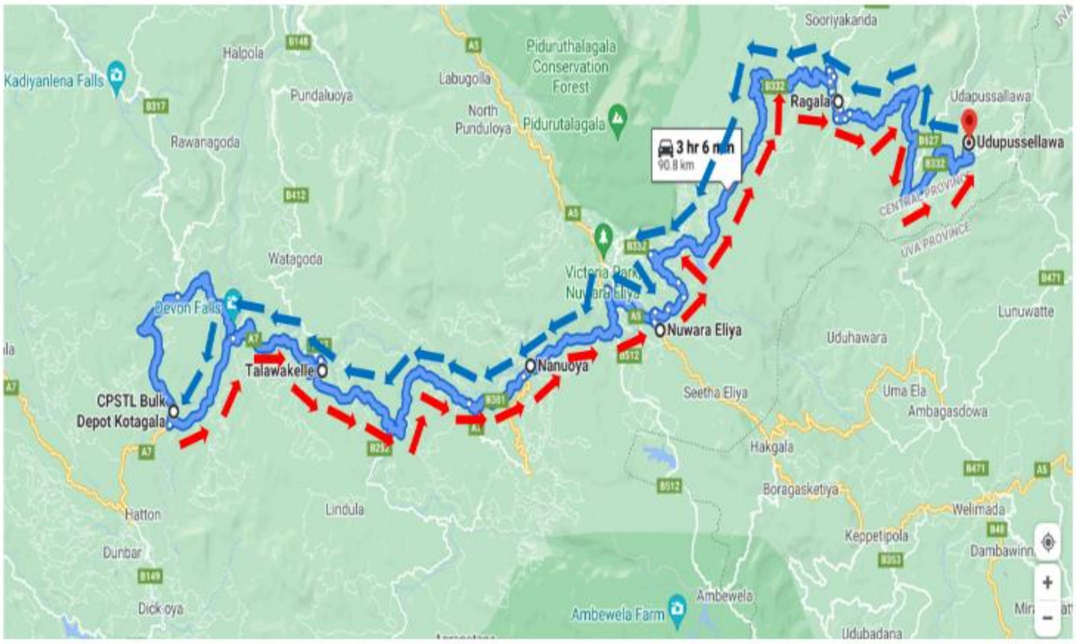


Table 3 shows the starting and ending town of each sub-tours of cluster 2 relevant to Kotagala Depot, along with optimal distances traveled **(**google distance**)** and the total distance travelled inside cluster 2 (total milk run).

Table 3: Starting and ending nodes of cluster 02- Kotagala depot

Starting node	Ending node	Distance Travel	Average Daily Demand: Volume in liters	Remain Diesel
KOTAGLA DEPOT	U.K. BUDDHADASA	13	5912.5	27087.5
U.K. BUDDHADASA	OKMART	18.1	5166.07	21921.43
OKMART	R A D J RANA	2.3	2396.43	19525
R A D J RANA	M UDAYAKUMAR	4	805.36	18719.64
M UDAYAKUMAR	MASKELIYA MPCS	8.5	1826.79	16892.85
MASKELIYA MPCS	MASKELIYA MPCS	9.5	4066.07	12826.78
MASKELIYA MPCS	K.A. JOTHIPALA	21.3	707.14	12119.64
K.A. JOTHIPALA	GINIGATHENA	14	3633.43	8486.21
GINIGATHENA	HIRUN	16	7523.21	963
HIRUN	KOTAGLA DEPOT	37.8	0	963
Total distance Traveled inside cluster 2			**144.5**	**km**
Total Volume within-cluster (Volume in Liters)			**32037**	**liters**

The optimal path of cluster 2- (Kotagala Depot) is shown in Figure 3.

Figure 3: Optimal path of Cluster 02- Kotagala depot

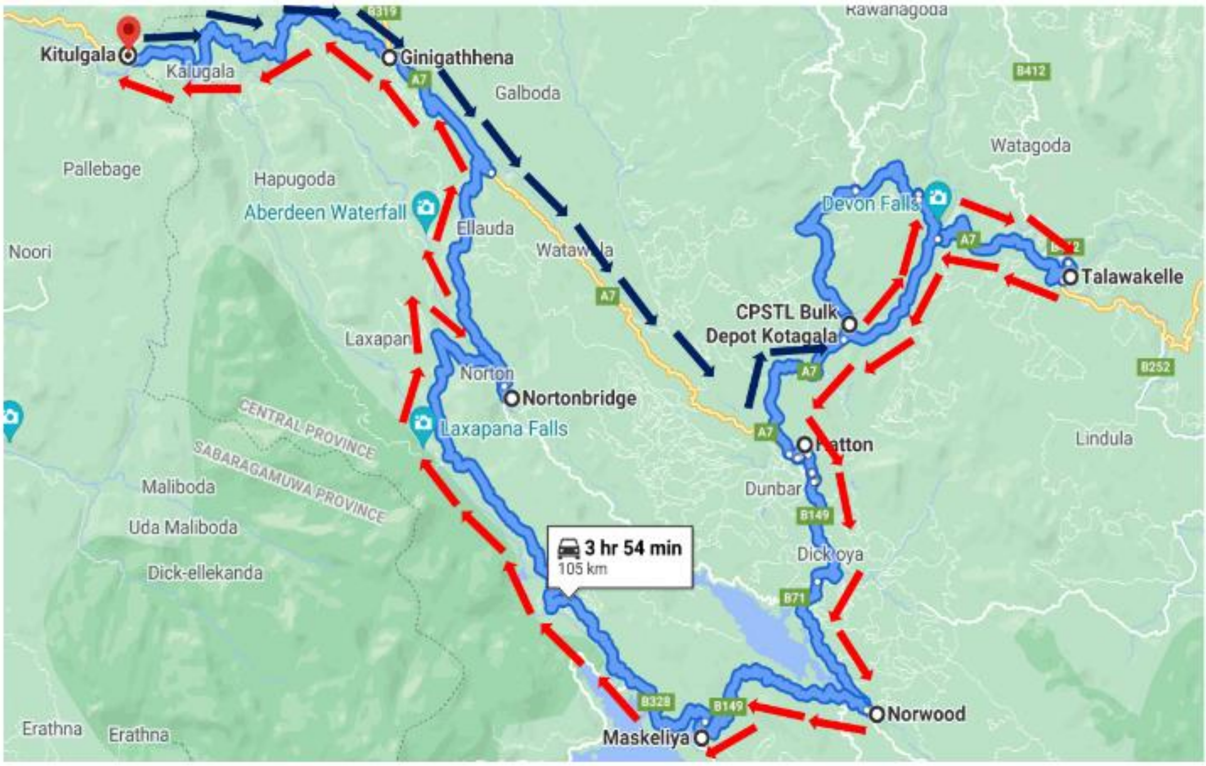


Table 4 shows the starting and ending town of each of the sub-tours of cluster 3 relevant to Kotagala Depot, along with optimal distances traveled **(**google distance**)** and the total distance traveled inside cluster 3 (total milk run).

Table 4: Starting and ending nodes of cluster 03- Kotagala depot

Starting node	Ending node	Distance Travel	Average Daily Demand: Volume in liters	Average Daily Demand: Remain Diesel
KOTAGLA DEPOT	M.WEERASINGHE	2.5	5617.86	27382.14
M.WEERASINGHE	PUNDALU OYA	24.5	2475	24907.14
PUNDALU OYA	KOTAGLA DEPOT	27	0	24907.14
Total distance Traveled inside the cluster 3			**54**	**km**
Total Volume within-cluster (Volume in Liters)			**8092.86**	**liters**

The optimal path of cluster 3- (Kotagala Depot) is shown in Figure 4.

Figure 4: Optimal path of Cluster 03- Kotagala depot

Likewise, all the milk runs of each cluster are found using the proposed routing algorithm, and Table 5 shows the results of the calculations. The below table shows the total distance traveled and total volume in liters of each cluster.

Table 5: Cluster arrangement of Kotagala depot

Depot	Cluster	Total traveled distance in the cluster (Milk run) (km)	Capacity Volume in liters
Kotagala	Cluster 1	143.3	28167.86
	Cluster 2	144.5	32037
	Cluster 3	54	8092.86

3.4. Calculation of the transportation cost of the existing method

Table 06 shows the transportation cost analysis under the existing system of Kotagala depot. It shows the calculation of an average daily transport cost. They have a fixed price for the first 16 kilometers and charge a rate of 0.01055 for the remaining extra per kilometer. There are five types of bowsers, and they are divided according to their capacities. They are 6600 liters, 13200 liters, 19800 liters, 26400 liters, and 33000 liters respectively.

Table 6: Transportation cost analysis on existing system

Location name	Average Daily Sales Qty Liters Diesel	Current Depot to LFS	Bowser Cost (More than 16 Km) without FC	Total Transport Cost
D & T ORG	3,201.79	68.2	2,304	2,304
NAWA MPCS LTD	3,417.86	53.7	1,936	1,936
HIRUN	7,523.21	37.8	3,000	3,000
D.D. KASTHURI	18,542.86	35.8	7,003	8,183
K.A. JOTHIPALA	707.14	28.9	216	1,396
PUNDALU OYA	2,475.00	27	705	705
M.H. SARATH	2,769.64	26.3	768	768
GINIGATHENA	3,633.93	25.4	974	974
MASKELIYA	4,066.07	25.3	1,085	1,085
MASKELIYA	1,826.79	16.5	318	318
U.K. BUDDHA	5,912.50	12	529	1,709
MS.M.Y. HEMA	235.71	11.5	21	1,201
OKMART	5,166.07	8	308	1,488
R A D J RANA	2,396.43	7.5	143	1,323
M UDAYA	805.36	7.5	48	1,228
M.WEERASIN	5,617.86	1.5	502	1,682
Reverse transport cost Route 01				2389.50
Reverse transport cost Route 02				5442.75
Reverse transport cost Route 03				2175.63
Reverse transport cost Route 04				2566.50
Reverse transport cost Route 05				4343.88
Average Daily Transport Cost				**46,218.61**

3.5. Calculation of the total transportation cost of the proposed method

Table 07 shows the transportation cost analysis under the proposed system of Kotagala depot. It shows the calculation of an average daily transport cost. They have a fixed price for the first 16 kilometers and charge a rate of 0.01055 for the remaining extra per kilometer. There are five types of bowsers, and they are divided according to their capacities. They are 6600 liters, 13200 liters, 19800 liters, 26400 liters, and 33000 liters, respectively.

Table 7: Transportation cost analysis on proposed system

Name	Annual Sales Quantity in Liters	Monthly Sales Quantity in Liters	Average Daily Transport Cost (RS)
D & T ORG	1,075,800	89,650	2303.72
NAWA MPCS	1,148,400	95,700	1936.34
HIRUN	2,527,800	210,650	3000.18
D.D. KASTHURI	6,230,400	519,200	7003.45
K.A. JOTHIPALA	237,600	19,800	215.6
PUNDALU OYA	831,600	69,300	705
M.H. SARATH	930,600	77,550	768.48
GINIGATHENA	1,221,000	101,750	973.78
MASKELIYA	1,366,200	113,850	1085.3
MASKELIYA	613,800	51,150	318
U.K. BUDDHA	1,986,600	165,550	1180.00
MS.M.Y. HEMA	79,200	6,600	1180.00
OKMART	1,735,800	144,650	1180.00
R A D J RANA	805,200	67,100	1180.00
M UDAYA	270,600	22,550	1180.00
M.WEERA	1,887,600	157,300	1180.00
Reverse transport cost Cluster 01			5877.88
Reverse transport cost Cluster 02			8119.88
Reverse transport cost Cluster 03			2175.63
Average Daily Transport Cost			**31267.73**

In the current system, distribution is done daily basis, but with the new system, delivery of Lanka Auto Diesel will be replaced by high-capacity Bowsers, which means that the LAD can be delivered daily at a reduced cost, and the cost is beared by the cluster as shown in the following cost tables below. It also includes a fixed cost for each bowser and some rates for every liter of LAD delivered to the Kotagala depot filling stations. Here, the Bowsers take a fixed price for the first 16 kilometers and charge a rate of 0.01055 for the remaining extra per kilometer. The capacity of the bowsers is 6600 liters, 13200 liters, 19800 liters, 26400 liters, and 33000 liters, respectively.

The tables above show the optimal distance traveled in each of the 3 clusters relevant to Kotagala Depot. Further, total milk runs under the proposed heuristics method and finally, the Total transportation cost of the Kotagala Depot can be calculated.

3.6. Total transportation cost based on existing method and propose method

Tables 6 and 7 show daily cost differences between the two systems. The Ceylon Petroleum Corporation fixed all costs, and the total distance in kilometers also fixed. In the existing system, there are more than 5 bowsers to cover the daily demand in Kotagala demand points, but the proposed system only needs 33000L capacity two bowsers and 13200L capacity one bowser to cover all the demand points in the Kotagala depot. Moreover, the existing system transport cost is included a fixed cost of Rs.1180/= for each bowser which travels more than 16 kilometers, because the proposed system plans to outsource the bowsers.

The daily Total transport cost of the existing system is Rs. 46218.61, and the daily total transport cost of the proposed system was Rs. 31267.73. Finally, the proposed systems bring a saving of Rs. 14950.88 per day, a 32.35% savings from the existing system. Table 8 shows the comparative study of the Existing .

Table 8: A comparative study of the Existing method and Proposed method

Total Transportation Cost for Existing System	46218.61
Total Transportation Cost for Proposed System	31267.73
Total Cost saving per day through new heuristic compared to the Existing Model	**14950.88 (32.35 %)**

4. Conclusion and recommendation

We have developed a central depot strategy based on secondary data collected from Ceylon Petroleum Corporation's SAP ERP System and Sales data report in Ceypetco. The total demand points (1621 filling stations) of Sri Lanka have been divided into two main terminals and 13 (regional depots) demand regions, and the demand value of each point is identified. After finding the locations of each demand point, a new route-finding algorithm was used to find the optimal path between clusters at each depot. The new route-finding algorithm was solved using MS Excel software. The Central depot capacity plan, cost comparison of the existing model, and the proposed model, including Transport cost, have been embedded in this research. The computational investigation highlights the cost savings that can be induced by our proposed method. These savings can be as significant as 32.35 % compared to the company's existing method. Central Depot Vehicle Routing Problem based on web-based Application modelling technique may be applied for better results of the currently studied problem in this paper. In the future, the research scope of the problem will lie in this direction. Furthermore, this research can be used by future researchers to do this to all the regionals depots and all the petroleum products in Ceylon Petroleum Corporation.

Individuals in the company should be trained to gain innovative and brainstorming ideas. In such training, their skills and mindset need to be improved to be a better and skilful employee in the company. For Future researchers. This study has applied only for one product and one regional depot of the company. Researcher already has all the assets and information (SAP ERP System) related to develop this study for the whole supply chain of the company. (All regional depots & All petroleum products).

Moreover, the researcher recommended a particular concern on the Optimal supply chain network, which was developed using the Ceylon Petroleum Corporation database (SAP) under the guidance of the Senior Management of the Research & Development Department.

Acknowledgement

The authors thank the anonymous reviewers for their suggestions.

Ethics approval and consent to participate

Not applicable.

Availability of data and material

The data are available on request.

Competing interests

The author declares that he has no competing interests.

Funding

This work received no funding.

Citation information

Jayarathna, N. (2024). Optimizing petroleum redistribution in Sri Lanka: A cost-benefit transportation model. *Journal of Sustainable Development of Transport and Logistics, 9*(1), 121-136. doi:10.14254/jsdtl.2024.9-1.9.

References

Arnold, F., Gendreau, M., & Sörensen, K. (2019). Efficiently solving very large-scale routing problems. *Computers & operations research*, *107*, 32-42. https://doi.org/10.1016/j.cor.2019.03.006

Azi, N., Gendreau, M., & Potvin, J. Y. (2010). An exact algorithm for a vehicle routing problem with time windows and multiple use of vehicles. *European Journal of Operational Research*, *202*(3), 756-763. https://doi.org/10.1016/j.ejor.2009.06.034

Chandrasekaran, G. (2010). *Optimization model to enhance the petroleum distribution network in Sri Lanka*, pp. 3095-3104.

De Silva, A. (2001). Combining constraint programming and linear programming on an example of bus driver scheduling. *Annals of Operations Research*, *108*(1), 277-291. https://doi.org/10.1023/A:1016075431943

Dantzig, G. B., & Ramser, J. H. (1959). The truck dispatching problem. *Management Science*, *6*(1), 80-91. https://doi.org/10.1287/mnsc.6.1.80

Drexl, M. (2012). Rich vehicle routing in theory and practice. *Logistics Research*, *5*, 47-63. https://doi.org/10.1007/s12159-012-0080-2

Gendreau, M., Laporte, G., & Potvin, J.Y. (2009). Metaheuristics for the VRP. In P*. Toth and D. Vigo, Eds., The Vehicle Routing Problem, SIAM Monographs on Discrete Mathematics and Applications, Philadelphia*, 2002, pp. 129-154. https://doi.org/10.1137/1.9780898718515.ch6

Goetschalckx, M. (2011). Supply Chain Engineering. *Springer,* New York. https://doi.org/10.1007/978-1-4419-6512-7

Ganepola, D. D., Jayarathna, N.D., & Madhushani, G. (2018). An intelligent cost optimized central warehouse and redistribution root plan with truck allocation system in Colombo region for Lion Brewery Ceylon PLC. *Journal of Sustainable Development of Transport and Logistics*, *3*(2), 66-73. https://doi.org/10.14254/jsdtl.2018.3-2.4

Jayarathna, D.G.N.D., Lanel, G.H.J., & Juman, Z. (2019). A contemporary recapitulation of major findings on vehicle routing problems: models and methodologies. *International Journal of Recent Technology and Engineering (IJRTE)*, *8*(2S4), 581-585. https://doi.org/10.35940/ijrte.B1115.0782S419

Jayarathna, N., Lanel, J., Juman, S., & Kankanamge, C.A. (2019). Modelling of an Optimal Outbound Logistics System (A Contemporary Review Study on effects of Vehicle Routing, Facility Location and Locational Routing Problems) *International Journal of Humanities and Social Science Invention (IJHSSI)*, 08(10), 08-30.

Jayarathna, N.D., & Jayawardene, C.J. (2019). Application of Clusters in a Transportation Network. *Journal of Mathematics and Informatics (JOMI)*, 17. https://doi.org/10.22457/jmi.130aav17a3

Jayarathna, N., Lanel, J., & Juman, Z. A. M. S. (2020). Five years of multi-depot vehicle routing problems. *Journal of Sustainable Development of Transport and Logistics*, *5*(2), 109-123. https://doi.org/10.14254/jsdtl.2020.5-2.10

Jayarathna, N., Lanel, J., & Juman, Z. A. M. S. (2021). Survey on ten years of multi-depot vehicle routing problems: mathematical models, solution methods and real-life applications. *Sustainable Development Research*, *3*(1), 36. https://doi.org/10.30560/sdr.v3n1p36

Jayarathna, D.G.N.D., Lanel, G.H.J. & Juman, Z.A.M.S. (2021). Modeling a cost benefit transportation model to optimize the redistribution process: Evidence study from Sri Lanka, *Journal of Sustainable Development of Transport and Logistics*, *6*(2), 43-59. https://doi.org/10.14254/jsdtl.2021.6-2.3.

Jayarathna, D.G.N.D., Lanel, G.H.J., & Juman, Z.A.M.S. (2021). An intelligent cost-optimized warehouse and redistribution root plan with truck allocation system: Evidence from Sri Lanka. *Journal of Business and Social Science Review*, 2(10).

Koç, Ç., Laporte, G., & Tükenmez, İ. (2020). A review of vehicle routing with simultaneous pick-up and delivery. *Computers & Operations Research*, *122*, 104987. https://doi.org/10.1016/j.cor.2020.104987

Laporte, G. (2009). Fifty years of vehicle routing. *Transportation science*, *43*(4), 408-416. https://doi.org/10.1287/trsc.1090.0301

Misni, F., & Lee, L. S. (2017). A review on strategic, tactical and operational decision planning in reverse logistics of green supply chain network design. *Journal of Computer and Communications*, *5*(8), 83-104. https://doi.org/10.4236/jcc.2017.58007

Nagy, G., & Salhi, S. (2005). Heuristic algorithms for single and multiple depot vehicle routing problems with pick-ups and deliveries. *European Journal of Operational Research*, *162*(1), 126-141. https://doi.org/10.1016/j.ejor.2002.11.003

Privé, J., Renaud, J., Boctor, F., & Laporte, G. (2006). Solving a vehicle-routing problem arising in soft-drink distribution. *Journal of the Operational Research Society*, *57*(9), 1045-1052. https://doi.org/10.1057/palgrave.jors.2602087

Rousseau, L. M., Gendreau, M., Pesant, G., & Focacci, F. (2004). Solving VRPTWs with constraint programming based column generation. *Annals of Operations Research*, *130*, 199-216. https://doi.org/10.1023/B:ANOR.0000032576.73681.29

Sachini, W. W. N., Weerabahu, W. M. S. K., & Wickramarchchi, R. (2019). Optimization model to enhance the petroleum distribution network in Sri Lanka. In *Proceedings of the International Conference on Industrial Engineering and Operations Management* (Vol. 5, No. 7).

Sitek, P., & Wikarek, J. (2019). Capacitated vehicle routing problem with pick-up and alternative delivery (CVRPPAD): model and implementation using hybrid approach. *Annals of Operations Research*, *273*(1), 257-277. https://doi.org/10.1007/s10479-017-2722-x

Vidal, T., Laporte, G., & Matl, P. (2020). A concise guide to existing and emerging vehicle routing problem variants. *European Journal of Operational Research*, *286*(2), 401-416. https://doi.org/10.1016/j.ejor.2019.10.010

Yasaman, J. (2015). *Optimization model to enhance the petroleum distribution network in Sri Lanka*, pp. 3095-3104.