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Industrial vehicle routing problem: a case study

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Abstract
This study is motivated by a real-world application of ABC (Pvt) Ltd., a well-known FMCG (fast-moving consumer goods) industry. The industry have nine agents (in two operating regions) from which it can serve its 5483 clients. We focus on this industry's outbound logistics in its two operating regions, namely Colombo and Gampaha, while taking into account its distribution and current decentralized redistribution processes, since additional routing costs have been identified in the existing setup. The goal of this study is to implement a better route plan that optimizes the truck allocation system at the lowest possible costs of transportation, warehouse, and administration. First to determine a best location for the new facility, the gravity model is used to pinpoint the exact location of the central warehouse. Then a centralized delivery strategy is applied to establish a better path between the sub-clusters. The performance of this centralized policy is evaluated on a real-world case study data. The relative cost benefit/saving (34%) of the centralized distribution system is then brought into focus and verified with solid statistics by comparing the overall cost of the centralized distribution system to the total cost of the existing decentralized distribution system. Finally, we highlight how decision-makers and policymakers in the logistics area might use our centralized delivery strategy to reduce extra-costs, particularly during the transportation of commodities.

Keywords: Industrial vehicle routing problem, Outbound logistics, Centralized delivery strategy, Truck allocation system

Introduction

In Sri Lanka, there is a growing, consistent demand for ABC (Pvt) Ltd.'s products, which varies according to social, cultural, seasonal, and environmental factors, with a predictable demand cycle. The company under consideration should have access to a distribution and redistribution master plan that reduces distribution and redistribution expenses. To achieve a competitive advantage in the FMCG market, maintaining a high level of service is critical. Due to the harsh climate in the outbound supply chain, some organizations also practice outsourcing their outbound operations to third-party logistics providers in order to decrease shipping, capital expenditures, and unanticipated risks.

Sunquick, Scan Jumbo peanuts, KotagalaKahata tea, Scan drinking water, N-joy Coconut oil, and Star Essences are among ABC Ltd's 47 Stock-Keeping Units (SKUs). In the

Colombo and Gampaha regions, nine distributors are operating, and ten redistribution trucks are used in the redistribution activity. Kadawatha, Dehiwala, Malabe, Homagama, Mahargama, Piliyandala, Yakkala, Negambo, Gampaha, and Angoda are the current distributors' locations.

In today's world, most businesses rely on representative distributors to reach out to customers. Distributors are critical components in the cooperation and coordination of supply and demand between the company and its consumers. This circumstance has increased the value of agencies, and enterprises must face higher distribution costs as a result. Companies, as well as their stakeholders, lose clear visibility of the links between the upstream and downstream supply chains in these conditions. ABC Ltd in Sri Lanka has designed a company-owned direct route plan within its outbound logistics covering the regions of Colombo and Gampaha to address this issue.

Existing decentralized company structure

ABC Ltd, exports and sells natural rubber of all types, including lightweight thick crepe rubber (TPC), striped smoky rubber (RSS), and dried coconut. Trade in commodities, rubber product production, industrial goods, and consumer goods are all part of the company's sector. This business also deals in sugar imports and wholesale to industrial customers. Welding equipment and consumables, as well as lighting, refrigeration, and air conditioning components, are all imported and sold by the company. It includes marine paints and protective coatings, as well as the import, production, and distribution of FMCG brand products. For a home sale, this comprises the Sun Quick bottling product range and scan-branded drinking water bottling. In the FMCG segment, the company also sells Jumbo Scan peanuts and Kotagala-Kahata tea. However, the researcher focused solely on the FMCG product line in this study.

Sunquick, Scan Jumbo peanuts, Kotagala Kahata tea, Scan drinking water, N-joy Coconut oil, and Star Essences are among Scan's well-known local and worldwide brands. The product scanning section has found a number of strategic channels with strong ties to Sri Lankan consumers. Traditional trade, modern trade, catering, and wholesale are the four distribution channels it employs. a robust direct sales network that stretches the length and breadth of the island. The most profitable segments of the group's internal trade activities are FMCG production, sale, and distribution.

In 2019, the company generated revenue of Rs. 6.8 billion and a net profit of Rs. 108.5 million, compared to revenue of Rs. 6 billion and a net profit of Rs. 185.5 million in 2018. The Sun Quick brand made the most significant contribution to sales growth. ABC Ltd's brands are extremely popular among Sri Lankans. Customer acquisition is also important, and superfluous costs in critical business sectors should be reduced. Because the supply chain and transportation procedures are so important in the distribution process, the company must set aside a significant portion of its budget for logistics.

13 agents' centers are established in Colombo and Gampaha, among many other regions where the company is involved in distribution. Extra routing expenses have been noted in the company's existing decentralized redistribution procedure, according to our analysis. As a result, the goal of this article is to propose a centralized distribution strategy to reduce logistics and routing costs.

Logistics is the most important aspect of supply chain management. Customer attraction is necessary to be a market leader in the FMCG business for bottled juice, and customer happiness should be a top focus. To achieve the two important elements listed above, an intelligent, rapid, reliable, and integrated logistics system should be implemented. An efficient logistics system is important since it improves the company's image and maintains a high level of customer service. ABC Ltd.'s inbound logistic activities include procurement, which includes imports and exports, as well as selecting and purchasing raw materials from domestic and international vendors. ABC Ltd.'s outbound logistics consists entirely of the distribution process, as depicted in Fig. 1

The company has been implementing decentralized distribution tactics, with 9 consignment distributors covering 5483 outlets in Colombo and Gampaha, and 10 cars used in the redistribution process.

Research problem

Developing a cost-effective mathematical route design model to lower ABC Ltd.'s FMCG items' exorbitant transportation expenses.

Description of the data

Secondary data from the SAP ERP system and other data from the agent operating database system are used in this study, including monthly goal demand, annual actual demand, annual demand quantity, and all distributor charges, among other things. Only a one-year data set is used in this study.

Significance of the research

Distribution and redistribution are critical procedures in a supply chain's outbound logistics that require careful planning and should be scrutinized in administration. Because the truck allocation procedure is so important in this regard, it must be meticulously planned in order to maintain a better degree of efficiency in distributor operations. The majority of businesses are unaware that the unexpected usage of trucks increases transportation costs. The complete supply chain will break up if the redistribution procedure is not prioritized. The researcher's goal is to locate an accurate place for dispersing ABC Ltd's products in the Colombo and Gampaha districts, as well as to implement a master plan to strengthen the distribution system in high-demand areas for optimal benefits.

Through this, centralized distribution strategies will help to:

- Decide on the best site for a central warehouse.
- A cost-optimized redistribution truck allocation system
- A root design for smooth redistribution

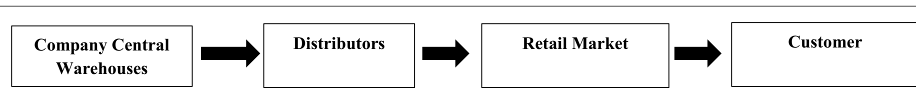

Fig. 1 Existing mode of distribution of ABC Ltd

The study addresses a research gap

The majority of the extant research focuses on inventory control in warehouses and mini-applications of trip plans, rather than a comprehensive approach. This study, on the other hand, focuses on transportation from the central warehouse to the merchants. Other research institutions are planning to deal with the challenges that occur as a result of the warehouse's expansion. The goal of this study is to determine the best route plan for products distribution, with the goal of introducing a system that could be used by most sectors for goods transportation.

The importance of transportation mathematical models for policymakers

From the standpoint of a logistician, securing the continuous flow of product from the producer to the ultimate consumer has become a critical task since transportation is a complicated network that includes a range of modes such as road, rail, air, and pipeline networks. When vehicle routing issues (VRP), which are one of the most common challenges in supply chain management, are effectively addressed, transportation management may be made more sustainable, resulting in a more efficient distribution system. As a result, various mathematical models and algorithms are devised in the quest for solutions to not only cut transportation costs but also to find the lowest cost possible based on the efficient use of the distribution area's resources. Most businesses seek to keep costs low and earnings high while retaining product quality. By focusing on the flows to minimize the total cost of the network, organizations can avoid congestion in the distribution process while also boosting decision-making power. As previously said, several techniques, such as exact optimization, which applies mathematical models in the search for a solution that ensures the exact solution for small to medium-sized issues, are required. Under various logistical processes, mathematical models are employed to look for actionable solutions to practical problems. When constructing the required mathematical models, several specific facts like as vehicle capacity, delivery times, amount, distance, and so on are taken into account. The mathematical models' links between the primary parts of the distribution process keep the equilibrium that happens inside the chain's main channels. Transportation networks are intertwined with telecommunications, electric power generation and distribution networks, supply chains, and other industries.

Related work

VRP is defined as the problem of determining the most cost-effective delivery directions or paths from a depot to a group of geographically scattered clients, with a focus on transverse constraints. VRP is in charge of product and service distribution in the context of supply chain and logistics management. This is critical for distribution management, and transporters should address it on a regular basis. The VRP is subject to some changes depending on the nature of the commodities being transported, the service value, and the characteristics of clients and vehicles. The "Truck Dispatching Problem," first given by Dantzig and Ramser (1959), entails modeling a fleet of homogeneous trucks to supply the demand for oil of a number of gas stations from a central hub while minimizing travel distance.

Contributions to rearranging this issue into a linear advanced optimization problem, which is commonly encountered in the domains of supply chain and operational management, can be further explained as a method of servicing a group of clients, geographically distributed around the central warehouse, using a fleet of trucks with various capacities, resulting in a VRP, which is one of the most widely used phenomena in the field of advanced linear programming.

Some types of VRPs were discovered to be improved, as well as ways for computing the shortest route. VRP is defined by Goetschalckx (2011) as the challenge of determining the shortest route for a vehicle that starts from one depot and travels to a number of different locations to meet a variety of client requests. Furthermore, each client with a specific capacity starts at one depot and ends at the main depot, and each client can only be toured once. VRP also includes a variety of heuristics and metaheuristics techniques. Laporte (2009) introduces them, as well as the contributions of (Gendreau et al. 2002; Daskin et al. 2005). Because of its widespread application and importance in constructing effective modes for minimizing transportation costs in distribution networks, the VRP is widely considered.

As a result, the goal of this paper is to develop an approximation of procedures that are suitable for discovering high-quality solutions in short time frames while also addressing the real-world problems that are described by large vehicle fleets and are positively influenced by logistics and distribution strategies.

Contemporary VRP software is being used by many public, private, and multinational companies in a large variety of industry sectors, and in particular, Coca-Cola Enterprises and Anheuser-Busch Inbev are generally significant Drexl (2012). The VRP has increased exponentially at a rate of 6% consistently, which creates a ubiquity for monitoring the expansions in the area and making a presentation of a strong indication of which substitutions and solution approaches are comparatively novel. (Sitek and Wikarek 2019) proposed a hybrid strategy for solving a novel VRP variant termed Capacitated Vehicle Routing Problem with Pick-up and Alternative Delivery (CVRPPAD). Heuristic methods for single and multiple-depot vehicle routing issues including pickups and deliveries were proposed by (Nagy and Salhi 2005). Azi et al. (2010) proposed a branch-and-price solution to a vehicle routing problem with time windows and numerous vehicle uses. With Constraint Programming Based Column Generation, Rousseau et al. (2004) proposed a solution approach for addressing VRPTWs. In a real-world application of bus driver scheduling, De Silva (2001) employed the Column Generation technique to integrate constraint programming and linear programming. Koç et al. (2021) conducted a thorough assessment of the current literature on the vehicle routing issue with simultaneous pickup and delivery VRPSPD, including mathematical formulations, algorithms, variations, case studies, and industrial applications.

The following is a list of extant and emerging vehicle routing problem variants (Vidal et al. 2020; Arnold et al. 2019; Ganepola et al. 2018). For solving very large-scale routing problems, they created a local search heuristic technique. For solving a vehicle-routing problem that arises in soft-drink distribution, Privét et al. (2006) offered three construction heuristics and an improvement approach. The VRP (Vehicle Routing Problem), which includes determining the lowest cost delivery directions or paths from a depot to a group of geographically distributed consumers in a transverse fashion, has focused on finding the best routes for fleets to reach their customers (Jayarathna and Jayawardene 2019; Jayarathna et al. 2019a, b; Jayarathna et al. 2020, 2021a, 2021c).

Despite doing multiple investigations on VRP, no suitable application has yet been discovered. Despite numerous studies based on the VRP, it does not appear to have very realistic applications (see review study on VRPs "Modeling of an Optimal Outbound Logistics System (A Contemporary Review Study on the Effects of Vehicle Routing, Facility Location, and Locational Routing Problems"). This has switched the focus to MDVRP: Multi-Depot Vehicle Routing Problem, a version of VRP, which is a more realistic case.

Assumptions and notation

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

Assumptions

1. The distance between two demand points in the Colombo region is calculated using Google Maps.
2. In theory, the shortest distance between two points is equal to the length of a straight line connecting the two sites. However, because considering the shortest distance is unrealistic, it is not taken into account here. Instead, just the Google distance value is taken into account by the researchers.
3. Time considerations, driver behavior, vehicle condition, unavoidable circumstances such as accidents, and weather conditions, all of which could alter the redistribution process, are not taken into account.`
4. Demand fluctuations are not tolerated.
5. There are no obstacles to the delivery of goods.
6. Trucks assigned to a cluster are only allowed to transport products within that cluster. Between the two separate clusters, none of the trucks transit.

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 ith depot, $i \in \{1, 2, 3 \ldots R\}$;
$n =$ 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;

$V = \{V_i/i \in \{1, 2, 3 \ldots n\}\}$, set of nodes/vertices;

$E = \{(i, j)|i, j \in V, i \neq j\}$, set of arcs in which (i, j) denotes the arc between node iandj;

C_i = Number of clusters arranged in ith depot; where $i \in \{1, 2, 3 \ldots R\}$.

n_r^i = Number of demand points in rth cluster at ith depot; where $i \in \{1, 2, 3 \ldots R\}$ and $r \in \{1, 2, 3 \ldots C_i\}$.

$Q_{i,r}$ = vehicle capacity of the rth cluster at ith depot; where $i \in \{1, 2, 3 \ldots R\}$ and $r \in \{1, 2, 3 \ldots C_i\}$.

q_{jr}^i = weight (demand) associated with the jth client, rth cluster at ith depot; where $i \in \{1, 2, 3 \ldots R\}, r \in \{1, 2, 3 \ldots C_i\}$ and $j \in \left\{1, 2, 3 \ldots n_r^i\right\}$.

$d_{V_j V_k}^{ir}$ = distance traveled from client V_j to client V_k in the rth cluster at ith depot; where $j, k \in \{1, 2, 3 \ldots n_i\}$

(Here $d_{V_j V_k}^{ir} = d_{V_k V_j}^{ir}$)

d_{ir} = Total distance traveled in the rth cluster at ith depot; where $i \in \{1, 2, 3 \ldots R\}$ and $r \in \{1, 2, 3 \ldots C_i\}$.

d_i = distance travel in the ith depot vehicle $i \in \{1, 2, 3 \ldots R\}$.

d = total distance travel through all clusters in all depots.

VC_{ir} = Original vehicle cost for assigning in rth cluster at ith depot; where $i \in \{1, 2, 3 \ldots R\}$ and $r \in \{1, 2, 3 \ldots C_i\}$.

r_{ir} = Annual depreciation ratio for vehicle assigned in rth cluster at ith depot; where $i \in \{1, 2, 3 \ldots R\}$ and $r \in \{1, 2, 3 \ldots C_i\}$.

$r_{ir} = \frac{\text{Annual depretiation value of a vehicle of the respective year assigned in the rth cluster at ith depot}}{\text{Value of this vehicle at the begining of the respective year}}$

t_{ir} = Number of years a vehicle is used in rth cluster at ith depot;

R_{ir} = Unit distance maintance cost coeffient ration for a vehicle used in rth cluster at ith depot where $i \in \{1, 2, 3 \ldots R\}$ and $r \in \{1, 2, 3 \ldots C_i\}$

$$R_{ir} = \frac{\text{Maintenance cost of a vehicle of the respective tour engaged in the rth cluster at ith depot}}{\text{Corresponding distance of the resptive tour in the rth cluster at ith depot}}$$

F_{ir} = Unit distance fuel cost coeffient ratio for a vehicle used in the rth cluster at ith depot, where $i \in \{1, 2, 3 \ldots R\}$ and $r \in \{1, 2, 3 \ldots C_i\}$

$$F_i = \frac{\text{Fuel cost of the of the vehicle of the respective tour in the rth cluster at ith depot}}{\text{Corresponding distance of the resptive tour of the rth cluster at ith depot}}$$

AVV_{ir}^t = Actual vehicle value which used t years in rth cluster at ith depot; where $i \in \{1, 2, 3 \ldots R\}$ and $r \in \{1, 2, 3 \ldots C_i\}$.

TC_{ir} = Transportation cost for the vehicle in rth cluster at ith depot where $i \in \{1, 2, 3 \ldots R\}$ and $r \in \{1, 2, 3 \ldots C_i\}$.

FC_{ir} = Fuel cost for the vehicle in rth cluster at ith depot; where $i \in \{1, 2, 3 \ldots R\}$ and $r \in \{1, 2, 3 \ldots C_i\}$.

MC_{ir} = Maintenance cost for rth cluster at ith depot; where $i \in \{1, 2, 3 \ldots R\}$ and $r \in \{1, 2, 3 \ldots C_i\}$.

TC_i = Transportation cost for ith depot, where $i \in \{1, 2, 3 \ldots R\}$.

Parameters for calculate warehouse operation and administration cost

(Allvariables define to calculate monthly cost).

K = Job opportunities exist in the depot.

L = Number of Utilities in the depot.

M = Vehicle administration cost types in the depot.

N = Additional expenses types in the depot.

W_i = Warehouse rent cost for the ith depot;

S_i = Budgeted Salary of the ith depot.

MW_i = Budgeted rental cost of the ith depot.

AE_i = Budgeted Additional cost of the ith depot.

S_p^i = Salary of the pth position employee at the ith depot; where $i \in \{1, 2, 3 \ldots R\}$, $p \in \{1, 2, 3 \ldots P\}$

$$X_p^i \begin{cases} 1, & \text{pth position employee used in the ith depot;} \\ 0, & \text{Otherwise} \end{cases}$$

E_l^i = Expenses for the lth utility bill at the ith depot; where $i \in \{1, 2, 3 \ldots R\}$, $l \in \{1, 2, 3 \ldots L\}$

$$Y_l^i \begin{cases} 1, & \text{lth utility used in the ith depot;} \\ 0, & \text{Otherwise} \end{cases}$$

VAC_{mr}^i = Vehicle administrations mth cost for rth cluster vehicle at the ith depot; where $m \in \{1, 2, 3 \ldots M\}$, $r \in \{1, 2, 3 \ldots C_i\}$, $i \in \{1, 2, 3 \ldots R\}$

$$Z_{mr}^i \begin{cases} 1, & \text{mth vehicle administration cost used in rth cluster vehicle at the ith depot;} \\ 0, & \text{Otherwise} \end{cases}$$

AE_n^i = Additional nth category Expenses at the ith depot; where $i \in \{1, 2, 3 \ldots R\}$, $n \in \{1, 2, 3 \ldots N\}$

$$XE_n^i \begin{cases} 1, & \text{nth category additional expenses used in the ith depot;} \\ 0, & \text{Otherwise} \end{cases}$$

TWOA = Total cost for Warehouse Operation and Administration.

AC = Administration Cost.

WOC = Warehouse and Operation Cost.

TTC = Total Transportation Cost.

TTWOA = Total cost for Transportation, Warehouse Operation and Administration.

Problem statement and model formulation

Problem statement

This study looked at the outward logistics of ABC Company, a well-known FMCG company, with a particular focus on the distribution and redistribution process in the Colombo and Gampaha regions. Additional routing expenses have been identified in the existing decentralized redistribution procedure due to inappropriate use of additional distances.

As a result of the redundant distances caused by inappropriate utilization of the used lorries, the company incurs additional transportation and warehouse costs in this system. As a result, the company's senior management wishes to perform further research in order to reduce the additional transportation, storage, and administration costs incurred in the metropolitan region. This is the goal of our efforts here.

The problem is defined as a completed directed graph $G=(V, A)$, where a tour of each cluster finishes at the destination node V_0, ($V_0 = V_{n+1}$). The researcher plans to find an optimal number of clusters in such a way that minimizes the total distance travelled considering all clusters, along with the total number of vehicles and relevant clients for each of the clusters. Let a depot be ready to provide products for a fleet of vehicles with capacity $Q_{i,}$, where $i \in \{1, 2, 3 \ldots D\}$. Our goal here is to present a method for reducing transportation, warehouse operation, and administrative costs. The nodes, excluding the central one, represent geographically spread customers. Each customer $i \in V - \{V_0\}$ has certain positive demand, such that $\sum_{j=1}^{n_i} \left(q_j^i\right) \leq Q_i$. The distance matrix is symmetric, since $d^i_{V_j V_k} = d^i_{V_k V_j}$ for all $j, k \in \{0, 1, 2, 3 \ldots n_i\}$, $i \in \{1, 2, 3 \ldots D\}$, $i \neq j$. The main distribution depot arranges the transportation facilities to the vehicles. That is, the distribution center organizes each of the vehicles according to the transportation plan and the corresponding route. The vehicles start their route from the distribution depot and return to the same depot after fulfilling the requirement. 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 costs during the completion of its tasks. Thus, a distribution depot has to arrange transportation routes in such a way that minimizes the total transportation cost of the whole system by taking those costs into account.

Between the present VRPs and our suggested new model in this work, there is a research gap. Our suggested model is novel in that it incorporates the expenses of fuel, maintenance, warehouse management, and administration, all of which are critical to transportation practice, into a unique perspective of cost coordination. The model's solution is creating optimal delivery and pickup routes that include (1) starting and terminating at the depot, (2) visiting each client exactly once, and (3) meeting all expectations. The overall cost includes the cost of fuel, vehicle maintenance, warehouse operation, and administrative expenses.

Identification of a new warehouse location by using the Gravity model

The researcher apply the gravity model (Andersson 1979) to determine the exact placement of the central warehouse.

$$X = \frac{\sum_i^n d_i \times x_i}{\sum_i^n d_i}, Y = \frac{\sum_i^n d_i \times y_i}{\sum_i^n d_i}$$

n, the number of demand points (1,2,3…,n)

(x_i, y_i), the given location coordinates with the ith demand point (latitude & longitude)

d_i, the demand associated with the ithdemand point.

(X, Y), the unknown location coordinate of the new warehouse facility.

In our study, the 5483 sub-clients in the Colombo and Gampaha regions were subdivided into 26 clients main demand points by clustering them. Figure 2 below shows

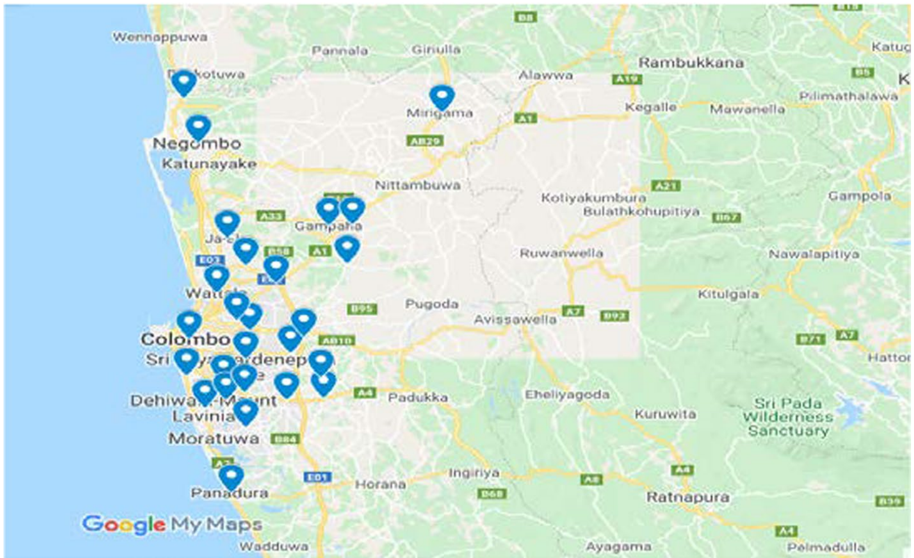

Fig. 2 Demand Locations in Colombo Region and Gampaha Region. Source: Geographical Map Sri Lanka

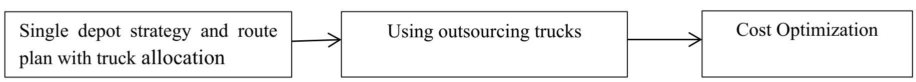

Fig. 3 Conceptual frame work

the distribution of the demand points for ABC company Products in Colombo and the Gampaha Region.

This research is based on the existing decentralized distribution strategy and proposes a new centralized distribution strategy. Figure 3 below shows the main delivery plan of the company.

We illustrate the gravity model with an example problem of demand and location coordinates (latitude and longitude) of the main clients of ABC Company in Colombo and the Gampaha region, as shown in Table 1.

The Gravity model equation was used to find the precise position of the central warehouse. The exact position of the central warehouse is given in Table 1 and is located at latitude 6.954871182 and longitude 79.91259064, which is situated nearby the west side of Peliyagoda.

Model construction

This section considers a transportation system for distributing FMCG products from a central depot using a group of vehicles. The distribution depot organizes each vehicle with a transportation plan and routes. 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 said 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

Table 1 Annual demands of ABC Company Products in Colombo and Gampaha region

Demand Points	Demand value	Latitude	Longitude	Latitude*D/V(X)	Longitude*D/V(Y)
Dehiwala	109,839,943.34	6.83667	79.8439262	750,939,445.47	8,770,052,330.22
Panadura	50,534,312.42	6.7291202	79.8944164	340,051,462.48	4,037,409,398.77
Nugegoda	30,837,303.75	6.8656182	79.8706401	211,717,153.84	2,462,995,189.16
Boralasgamuwa	32,881,664.51	6.8365293	79.8897056	224,796,462.86	2,626,906,497.43
Battaramulla	107,556,545.54	6.9001015	79.9029844	742,151,081.22	8,594,088,980.47
Maharagama	79,324,049.21	6.8502516	79.9073489	543,389,695.00	6,338,574,476.17
Kottawa	51,370,635.27	6.8690953	79.9797876	352,869,789.30	4,108,612,497.87
Homagama	30,820,660.27	6.8451342	79.9887083	210,971,555.67	2,465,304,803.77
Malabe	34,619,046.57	6.9043629	79.9479226	239,022,460.75	2,767,720,855.37
Angoda	43,510,655.99	6.9333996	79.9161694	301,676,764.84	3,477,204,954.80
Piliyandala	54,879,871.97	6.7896893	79.9012898	372,617,279.51	4,384,972,554.57
Kaduwela	6,624,608.59	6.9299975	79.9733482	45,908,520.97	529,792,129.51
Maradana	261,063,935.94	6.926745	79.8605224	1,808,323,312.95	20,848,702,303.98
Wattala	168,494,022.45	6.989402	79.885278	1,177,672,457.50	13,460,191,824.71
Wellawatta	31,208,418.96	6.8738385	79.8611775	214,521,631.74	2,492,341,085.72
Gampaha	53,352,830.66	7.083605	80.006455	377,930,378.05	4,268,570,845.58
Kelaniya	22,525,756.47	6.9559081	79.9169459	156,687,091.86	1,800,189,660.82
Kadawatha	61,080,181.62	7.0097642	79.942525	428,157,670.46	4,882,903,946.33
Ja-Ela	17,784,276.89	7.0742115	79.8937204	125,809,736.08	1,420,852,045.18
Negambo	142,750,892.67	7.1963407	79.829926	1,027,284,058.88	11,395,793,198.20
Yakkala	28,513,346.82	7.0877703	80.0232392	202,096,052.76	2,281,730,373.13
Meerigama	47,583,630.89	7.253295	80.1096746	345,138,112.01	3,811,909,186.86
Weliweriya	7,770,027.05	7.0346322	80.019072	54,659,282.47	621,750,353.84
Ragama	6,554,858.77	7.0306524	79.9232021	46,084,933.58	523,885,302.59
Kochchikade	13,327,673.99	7.2628576	79.8634837	96,796,998.30	1,064,394,474.15
Paliyagoda CWH	1,569,243,475.83	6.954871182	79.91259064	10,913,886,227.89	125,402,311,494.85

a load capacity limit and will incur fuel consumption and usage costs while completing its tasks. Thus, the central depot has to arrange transportation routes in a way that minimizes the total transportation cost of the whole system by taking those costs into account. Thus, our proposed VRP model in this paper, in comparison with the existing VRP models, is new in the sense that we include the fuel consumption cost and usage cost, which are essential to transportation practice from the perspective of coordinating the economic cost. Here, the fuel consumption cost mainly comprises the oil cost and the usage cost (measured by the time consumed and mainly including the depreciation cost, the operators' salaries, the insurance expenses, etc.).

Let $G=(V,H)$ be a complete directed graph with $V=\{V_0,V_1, V_2, \ldots,V_n , V_{n+1}\}$,as the set of nodes $(n+1)$ and $E=\{(i, j) \mid i, j\in V, i \neq j\}$as the set of edges, where node V_0 represents the depot and tour of each cluster should finish at the destination node $V_0, (V_0 = V_{n+1})$. Here depot for a fleet of D vehicles with the different Capacity Q_i, where $i \in \{1, 2, 3 \ldots D\}$. After excluding central depot remaining nodes represent geographically spread customers. Each customer $i \in V-\{V_0\}$ has a certain positive demand such that $\sum_{j=1}^{n_i} \left(q_j^i\right) \leq Q_i$..

Following Jayarathna et al. (2021a, b, c, d), a cost model of transportation, warehouse operation, and administration was used to solve our industrial vehicle routing problem.

Model formulation for Calculate Fuel and Maintenance cost of Transportation

$AVV_{ir}^{t} = VC_{ir} - (r_{ir})^{t} VC_{ir}$, vehicle value which used t years in rth cluster vehicle at ith 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 ∈ {0, 1, 2, 3 . . . 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 ∈ {0, 1, 2, 3 . . . 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

$$TTC = \sum_{i=1}^{R} \sum_{r=1}^{C_i} [AVV_{ir}^{t}] * [R_{ir} + F_{ir}] \sum_{j=0,\, j\neq k}^{n_r^i} \min(d_{V_j V_k}^{ir}), \text{ where } j, k \in \left\{0, 1, 2, 3, \ldots, n_r^i\right\}$$
$$\text{where } r \in \{1, 2, 3 \ldots C_i\}, i \in \{1, 2, 3 \ldots R\} \tag{1}$$

$d_{ir} = \sum_{j=0, j\neq k}^{n_r^i} \min(d_{V_j V_k}^{ir})$, where i ∈ {1, 2, 3 . . . .R} and j , k ∈ $\left\{0, 1, 2, 3 \ldots n_r^i\right\}$, $V_0^i = V_{n_i,+1}^{i}$,

distance travel in the rth cluster vehicle at ith depot vehicle which Eachtour start from V_0^i and end on $V_{n_i,+1}^{i}$.

$d_i = \sum_{i=1}^{R} (d_{ir})$, where r ∈ {1, 2, 3 . . . C_i}, i ∈ {1, 2, 3 . . . R}, distance travel in the ith depot vehicle

$$d = \sum_{i=1}^{R} (d_i), \text{ where } r \in \{1, 2, 3 \ldots C_i\}\ i \in \{1, 2, 3 \ldots R\} \tag{2}$$

$$\sum_{j=1}^{n_r^i} \left(q_j^{ir}\right) \leq Q_{i,r}, \quad \text{where } r \in \{1, 2, 3 \ldots C_i\}, i \in \{1, 2, 3 \ldots R\}, \tag{3}$$

Constraint (3) ensures that the total demand arises in the rth cluster vehicle at ith depot cannot exceed the vehicle capacity.

$$n_i = \sum_{r=1}^{C_i} \left(n_r^i\right), \text{ where } r \in \{1, 2, 3 \ldots C_i\}, i \in \{1, 2, 3 \ldots R\} \tag{4}$$

$$n = \sum_{i=1}^{R} (n_i), \text{ where } \quad i \in \{1, 2, 3 \ldots R\}, \tag{5}$$

$$n = \sum_{i=1}^{R} \sum_{r=1}^{C_i} n_r^i, \text{ where } r \in \{1, 2, 3 \ldots C_i\}, i \in \{1, 2, 3 \ldots R\} \tag{6}$$

$$d^{ir}_{V_jV_k} + d^{ir}_{V_kV_l} \geq d^{ir}_{V_jV_l} \text{ for all j, k, l} \in \{0, 1, 2, 3 \ldots n_i\} \tag{7}$$

The distance matrix is symmetric, i.e.

$$d^{ir}_{V_jV_k} = d^{ir}_{V_kV_j} \text{ for all } j, k \in \left\{0, 1, 2, 3 \ldots n^i_r\right\}, i \in \{1, 2, 3 \ldots R\}, i \neq j \tag{8}$$

To serve the customers, we have to design routes for a fleet with C_i vehicles distributed from ith depot, where, $i \in \{1, 2, 3 \ldots R\}$. Each route must start at the depot, visit a subset of customers and then return to the depot. This model is developed for the multi-depot system but can be used for the single depot to do all cost calculations.

Finding an optimal solution to this model is a lengthy process that takes a significant amount of time to complete (1). This type of model, on the other hand, has economic value, especially when it is used in conjunction with integrated supply chain management. As a result, many logistics solution providers have developed to meet this growing need, and corporations are willing to pay a premium for these custom-made solutions. Simultaneously, excel software has been developed to make accurate solutions to these mathematical models possible.

By coding the objective function and all constraints in a specific programming language, the solution can be reached faster and with fewer errors.

Total warehouse operation and administration cost calculation

$$\mathrm{TWOA} = \mathrm{AC} + \mathrm{WOC}$$

$$\mathrm{TWOA} = \sum_{i=1}^{R}\sum_{p=1}^{P} X^i_p{*}S^i_p + \sum_{i=1}^{R}\left[W_i + \sum_{l=1}^{L} Y^i_l{*}E^i_l, + \sum_{m=1}^{M}\sum_{r=1}^{C_i} Z^i_{mr}{*}VAC^i_{mr} + \sum_{n=1}^{N} XE^i_n{*}AE^i_n\right]$$

$$\mathrm{AC} = \sum_{i=1}^{R}\sum_{p=1}^{P} X^i_p{*}S^i_p, \text{ where i} \in \{1, 2, 3 \ldots R\}, p \in \{1, 2, 3 \ldots P\}$$

$$\mathrm{WOC} = \sum_{i=1}^{R}\left[W_i + \sum_{l=1}^{L} Y^i_l{*}E^I_l, + \sum_{m=1}^{M}\sum_{r=1}^{C_i}(Z^i_{mr}{*}VAC^i_{mr}) + \sum_{n=1}^{N} XE^i_n{*}AE^i_n\right], \text{ where i} \in \{1, 2, 3 \ldots R\},$$
$$p \in \{1, 2, 3 \ldots P\}, l \in \{1, 2, 3 \ldots L\}, n \in \{1, 2, 3 \ldots N\}$$

A mathematical formula for calculating the total cost of transportation, warehouse operation, and administration.

$$\mathrm{TTWOA} = \mathrm{TTC} + \mathrm{AC} + \mathrm{WOC}$$

$$\mathrm{TTWOA} = \sum_{i=1}^{R}\sum_{r=1}^{C_i}\{AVV_{ir}^{t}\}*\{R_{ir} + F_{ir}\}\sum_{j=0,\, j\neq k}^{n_r^i}\min(d_{V_jV_k}^{ir}) + \sum_{i=1}^{R}\sum_{p=1}^{P} X_p^i * S_p^i$$

$$+\sum_{i=1}^{R}\left[W_i + \sum_{l=1}^{L} Y_l^i{}^*E_l^i, + \sum_{m=1}^{M}\sum_{r=1}^{C_i} Z_{mr}^i{}^*VAC_{mr}^i + \sum_{n=1}^{N} XE_n^i{}^*AE_n^i\right]$$

$\sum_{k=1}^{P} X_k^i{}^*S_k^i < S_i,\ i \in \{1, 2, 3 \ldots R\}$, /Budget constrain for Salary of the depot;

$W_i < MW_i,\ i \in \{1, 2, 3 \ldots\ldots..R\}$, / Budget constrain for Rental cost of the depot;

$\sum_{n=1}^{N} XE_n^i{}^*AE_n^i < AE_i$, /Budget constrain for Additional cost of the depot;

$\sum_{j=1}^{n_r^i} \left(q_j^{ir}\right) \leq Q_{i,r}$,/Vehicle capacity constraint of each cluster;

where

$r \in \{1, 2, 3 \ldots C_i\}, j, k \in \left\{0, 1, 2, 3, \ldots, n_r^i\right\},\ i \in \{1, 2, 3 \ldots R\};\ p \in \{1, 2, 3 \ldots P\}, l \in. \{1, 2, 3 \ldots L\}, n \in \{1, 2, 3 \ldots N\}$

Analysis of the research

Existing route analysis method

The ABC company (nine consignment distributors in Colombo and Gampaha) uses decentralized distribution strategies for distributing FMCG product among 5483 clients in Colombo and Gampaha. ABC (Pvt) Ltd. runs eleven redistributing cars in Colombo and Gampaha. Figure 4 depicts the ABC Company's distributors in Colombo and Gampaha.

Sun Quick, Scan Jumbo peanuts, Kotagala Kahata tea, Scan drinking water, N-joy Coconut oil, and Star Essences are among Scan's well-known local and worldwide brands. Based on data from the SAP ERP system's annual sales report. In the Colombo and Gampaha regions, there are nine distributors, with five in the Colombo region

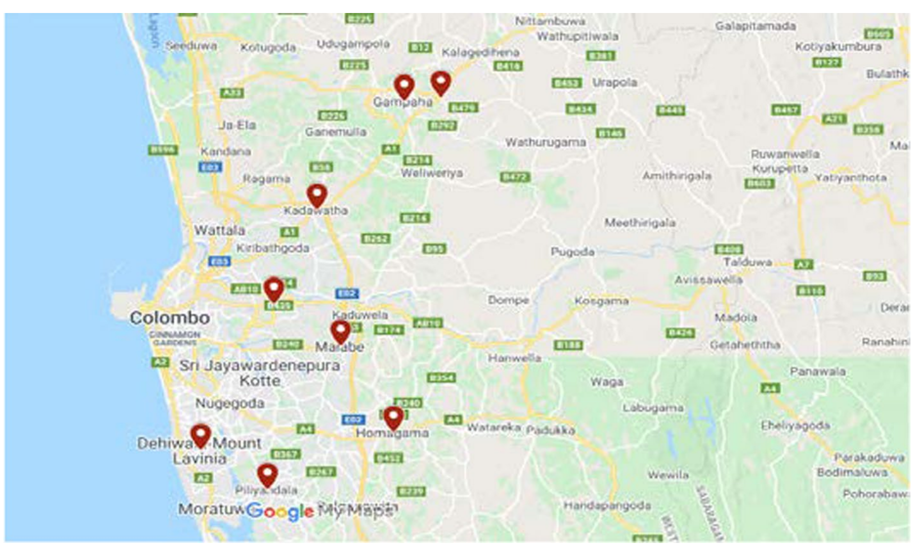

Fig. 4 Distributors of ABC Company in Colombo and Gampaha Regions

and four in the Gampaha region. The annual sales of distributors in the Colombo and Gampaha areas are shown in Table 2.

Calculation of the transportation cost—single depot cluster analysis vehicle routing method

To tackle our industrial vehicle routing problem, the researcher employed Jayarathna et al. (2021b)'s technique to determine total transportation, warehouse operating, and administrative expenses. First, we group clients into clusters based on their vehicle capacity and demand. Following this heuristic, the ideal number of clusters, as well as relevant customers, is discovered. Finally, by adding the transportation costs of each sub-cluster, the overall transportation cost is computed. The steps of the algorithm are listed below.

Algorithm: Jayarathna et. al. (2021b)'s Method

Step 01: Identify the location of the n demand points & their demands.

Step 02: Use gravity model formula to determine the optimal location of the Central Warehouse (V_0)

Step 03: Set $S_0 = \{V_1, V_2, V_3, \ldots\ldots\ldots V_n\}$, $A = \emptyset$, an empty set and k = 0

Step 04: Set t = 0, k = k+1, $S_0 = S_0 \cup A$, and define a new empty set S_k

Step 05: If $t \leq 1$,

let the distance from V_t to nodes of S_0 be $d_{V_tV_i}$, $V_i \in S_0$. Let V_r $(r = 1, 2, \ldots, n)$ at the minimum distance from V_t and set $V_{t+1} = V_r$. Set $d_{V_tV_{t+1}} = \min\{d_{V_tV_i}, V_i \in S_0\}$ and t = t +1.

Else

let the distance from V_l to nodes of S_0 be $d_{V_lV_i}$, $V_i \in S_0$. Let V_r $(r = 1, 2, \ldots, n)$ at the minimum distance from V_t and set $V_{t+1} = V_r$. Set $d_{V_lV_{t+1}} = \min\{d_{V_lV_i}, V_i \in S_0\}$ and t = t +1.

Step 06: If $t \leq 1$, insert V_r to S_k, assign $V_l = V_t$ and remove V_r from S_0 and go to Step 05.

Step 07: If $d_{V_0V_t} \geq d_{V_lV_t}$, insert V_r into S_k, remove Vr fromS_0 and assign $V_l = V_t$.

Else insert V_r into the set A, and remove V_r fromS_0.

Step 08: If t < n, go to Step 05

Step 09: If $A \neq \emptyset$, an empty set, go to Step 4.

Step 10: Stop.

Table 2 Average sales of Colombo Region and Gampaha Region

Distributor	Average Annual Demand (Values)	Average Annual Demand (Units)	Average Total Annual Demand (Values)	Average Total Annual Demand (Units)
Colombo District	1,168,000,000.00	1,993,677	1,569,243,475.83	3,353,443.00
Gampaha District	401,243,475.83	1,359,766		

Source: Constructed by the author based on SAP data

Comparative study

Calculation of the optimal distances between each pair of towns using Algorithm

Using the distances listed in the Table 1 above, create an optimum route plan for getting goods to all demand points. Although the conventional practice is to deliver the goods once a week, this process allows the distribution to be done once a month. A truck's capacity is estimated to be 77 cubic meters. It then moves to the demand point that is the least distance away from the central warehouse, and then to the shortest demand point. The cubic volume capacity travels to the end in this manner. The route designs that were obtained in this way are listed below. When the first capacity is depleted, it is renamed cluster 01, and the distribution process continues from the central warehouse to the other demand points, dividing Colombo and Gampaha's demand points into clusters.

The supplies are dispersed from the central warehouse to all demand sites via truck in this manner. The optimum pathways with distances for each cluster's solution are listed below. Table 3 lists the starting and ending locations for each of Cluster 1's sub tours, as well as the best distances traveled (Google distance) and the total distance traveled inside the cluster (total milk run).

The optimal path of cluster 1 is shown in Fig. 5.

Table 4 lists the starting and ending locations for each of Cluster 2's sub tours, as well as the best distances traveled (Google distance) and the total milk run.

The optimal path of cluster 2 is shown in Fig. 6.

The starting and ending locations of each of Cluster 3's sub tours, as well as the optimal distances traveled (Google distance) and the total milk run, are shown in Table 5.

The optimal path of cluster 3 is shown in Fig. 7.

The starting and ending locations of each of Cluster 4's sub tours, as well as the optimal distances traveled (Google distance) and the total milk run, are shown in Table 6.

The optimal path of cluster 4 is shown in Fig. 8.

Table 7 lists the starting and ending locations for each of Cluster 5's sub tours, as well as the best distances traveled (Google distance) and the total milk run.

The optimal path of cluster 5 is shown in Fig. 9.

Table 8 lists the starting and ending towns for each of Cluster 6's sub tours, as well as the best distances traveled (Google distance) and the total milk run.

The optimal path of cluster 6 is shown in Fig. 10.

Table 3 Clusters 01 route distance

Starting Town	Ending town	Distance traveled (Km)	Capacity cubic volume	Transshipment node
Peliyagoda	Kelaniya	2	10	No
Kelaniya	Angoda	3	7	Yes
Angoda	Battaramulla	6	30	Yes
Battaramulla	Malabe	5	9	Yes
Malabe	Athurugiriya	5	4	Yes
Athurugiriya	Kottawa	7	17	Yes
Kottawa	Peliyagoda	19	0	Yes
Total distance Traveled inside the cluster 1				47 km
Total Volume within cluster (Cubic Volume)				77

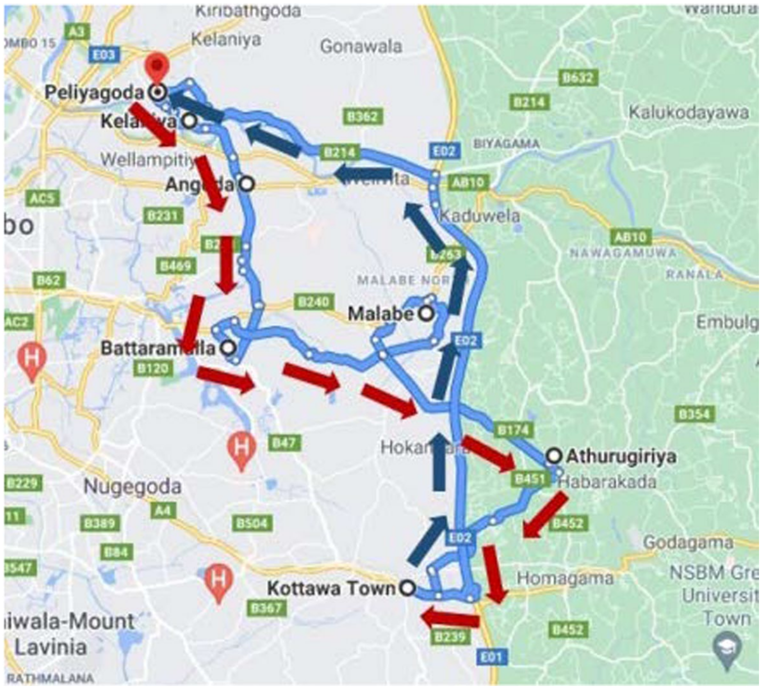

Fig. 5 Cluster 01 Route plan

Table 4 Clusters 02 route distance

Starting town	Ending town	Distance traveled (Km)	Capacity cubic volume	Transshipment node
Peliyagoda	Wattala	4	41	No
Wattala	Ragama	8	2	Yes
Ragama	Kadawatha	5	15	Yes
Kadawatha	Weliweriya	10	2	Yes
Weliweriya	Gampaha	7	15	Yes
Gampaha	Peliyagoda	21	0	Yes
Total distance Traveled inside the cluster 2				55 km
Total Volume within cluster (Cubic Volume)				75

Under the proposed strategy, Table 9 illustrates the ideal distance traveled in each of the six clusters as well as the total milk run.

Calculation of the transportation cost—single depot cluster analysis vehicle routing method

Delivery is currently done once a week, however with the new system, products are transported using a truck, which means they can be delivered once a month at a lower cost, and the cost is paid by the cluster, as stated in Table 11; cost tables for this are presented separately below. The cost of shipping, the cost of insuring goods, the cost of staff support, and the cost of others are all included (cost of refreshment). The vehicles pay a predetermined amount for the first 50 km and then charge $200 for each additional kilometer. The prime mover has a capacity of 77 cubic volumes.

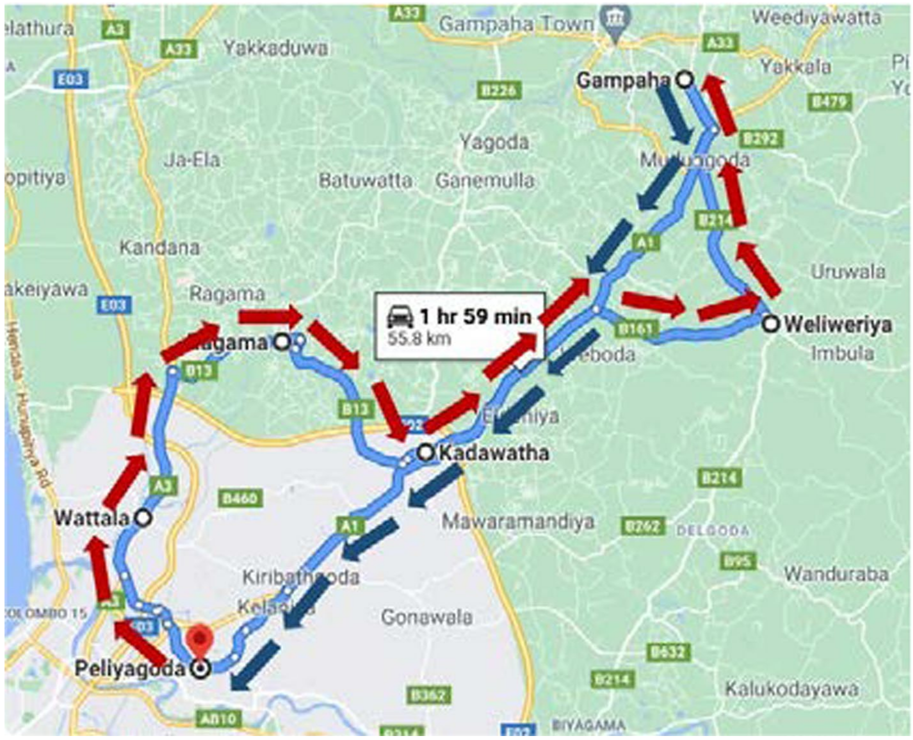

Fig. 6 Cluster 02 Route plan

Table 5 Clusters 3 route distance

Starting town	Ending town	Distance traveled (Km)	Capacity cubic volume	Transshipment node
Peliyagoda	Ja-ela	14	5	No
Ja-ela	Yakkala	17	8	Yes
Yakkala	Meerigama	24	12	Yes
Meerigama	Negambo	32	35	Yes
Negambo	Peliyagoda	33	0	Yes
Total distance Traveled inside the cluster 3				120 km
Total Volume within cluster (Cubic Volume)				60

Cluster 01 spans 47 km and holds 77 cubic meters of water, which is distributed to all demand sites in Kelaniya, Angoda, Baththaramulla, Malabe, Athurugiriya, and Kottawa. The cost of delivery to Cluster 01 is shown in Table 10, which covers transportation costs, goods and other expenses insurance, and other staff service salaries.

Cluster 02 spans 55 km and has a capacity of 75 cubic meters. It is supplied to all demand sites in Wattala, Ragama, Kadawatha, Weliweriya, and Gampaha. The cost of delivery to Cluster 02 is shown in Table 11, which comprises transportation costs, goods and other expenses insurance, and other staff service salaries.

Cluster 03 spans 120 km and holds 60 cubic meters of water, which is distributed to all demand sites in Ja-Ela, Yakkala, Meerigama, and Negambo, respectively. The cost

Fig. 7 Cluster 03 Route plan

Table 6 Clusters 04 Route Distance

Starting town	Ending town	Distance traveled (Km)	Capacity cubic volume	Transshipment node
Peliyagoda	Kaduwela	12	2	No
Kaduwela	Homagama	14	9	Yes
Homagama	Maharagama	10	22	Yes
Maharagama	Piliyandala	7	7	Yes
Piliyandala	Boralasgamuwa	5	9	Yes
Boralasgamuwa	Nugegoda	4	9	Yes
Nugegoda	Wellawatta	4	9	Yes
Wellawatta	Peliyagoda	15	0	Yes
Total distance Traveled inside the cluster 4				71 km
Total Volume within cluster (Cubic Volume)				67

of delivery to Cluster 03 is shown in Table 12 and comprises transportation costs, goods and other expenses insurance, and other staff service salaries.

Cluster 04 is supplied to all demand sites in Kaduwela, Homagama, Maharagama, Piliyandala, Boralasgamuwa, Nugegoda, and Wallewatta, and covers 71 km and has a capacity of 67 cubic volumes. The cost of delivery to Cluster 04 is shown in Table 13, which comprises transportation costs, goods and other expenses insurance, and other staff service salaries.

Cluster 05 spans 73 km and holds 40 cubic meters of water, which is provided to all demand sites in Dehiwala and Panadura, respectively. The cost of delivery to cluster 05 is shown in Table 14, which includes transportation costs, insurance for goods, other charges, and other personnel service pay.

Fig. 8 Clusters 04 Route plan

Table 7 Clusters 05 route distance

Starting town	Ending town	Distance traveled (Km)	Capacity cubic volume	Transshipment node
Peliyagoda	Dehiwala	18	28	No
Dehiwala	Panadura	20	12	Yes
Panadura	Peliyagoda	35	0	Yes
Total distance Traveled inside the cluster 5				73 km
Total Volume within cluster (Cubic Volume)				40

Cluster 06, with a daily capacity of 76 cubic meters and a length of 19.5 km, serves all demand locations in Kochchikade and Maradana, respectively. Table 15 shows the cost of delivery to Cluster 06, which includes transportation, goods and other expense insurance, and other staff service salaries.

Comparing salaries and wages in the current situation and the proposed system.
Employee salary will be compared to that of their coworkers in the study. Table 16 shows the results of the new system and the projected system, as well as staff analysis and pay.

In the existing system, the trucks are hired by the driver, and there is no warehouse manager, however in the proposed system, the trucks are hired by the driver, and the driver is not required to pay a separate salary. Furthermore, the existing system will distribute through 9 distribution centers, resulting in an increase in the number of employees, whereas the proposed method would distribute exclusively through the central warehouse, resulting in a decrease in the number of employees. The overall cost of

Fig. 9 Clusters 05 Route plan

Table 8 Clusters 06 route distance

Starting town	Ending town	Distance traveled (Km)	Capacity cubic volume	Transshipment node
Peliyagoda	Kochchikade	7	4	No
Kochchikade	Maradaana	4	72	Yes
Maradaana	Peliyagoda	8.5	0	Yes
Total distance Traveled inside the cluster 6				19.5 km
Total Volume within cluster (Cubic Volume)				76

salaries and wages in the existing system is Rs. 2,812,000, while the total cost of salaries and wages in the proposed system is Rs. 1,259,000.

Cost analysis of the total cost of the existing system and proposed system.

The goal of the study is to determine the cost of the new facility and compare it to the cost of the present system. The overall transportation, warehouse operating, and administration costs of the company's current system are shown in Table 17 below.

Fig. 10 Clusters 06 Route plan

Table 9 Monthly travel distance in kilometers

Cluster	Kilometers	Total Volume
1	47	77
2	55	75
3	120	60
4	71	67
5	73	40
6	19.5	76
Total	385.5 km	

Table 10 Cost of delivery to cluster 01

Cluster 01							
Description	**Cost**	**QTY**	**Distance**	**Fixed cost**	**Extra distance**	**Extra distance cost (1 km = Rs.200)**	**Total cost**
Transport Cost		77	47 km	35,000	0	0	35,000
Insurance for Goods	1300	77					100,100
Other Expenses	3400						3400
Supporting Staff Service Salary	3*3500						10,500
Total Cost							149,000

Table 11 Cost of delivery to cluster 02

Cluster 02							
Description	**Cost**	**QTY**	**Distance**	**Fixed cost**	**Extra distance**	**Extra distance cost (1 km = Rs.200)**	**Total cost**
Transport Cost		75	55 km	35,000	5 km	1000	36,000
Insurance for Goods	1300	75					97,500
Other Expenses	3400						3400
Supporting Staff Service Salary	3*3500						10,500
Total Cost							147,400

Table 12 Cost of delivery cluster 03

Cluster 03							
Description	**Cost**	**QTY**	**Distance**	**Fixed cost**	**Extra distance**	**Extra distance cost (1 km = Rs.200)**	**Total cost**
Transport Cost		60	120 km	35,000	70 km	14,000	49,000
Insurance for Goods	1300	60					78,000
Other Expenses	3400						3400
Supporting Staff Service Salary	3*3500						10,500
Total Cost							140,900

Table 13 Cost of delivery cluster 04

Cluster 04							
Description	**Cost**	**QTY**	**Distance**	**Fixed cost**	**Extra distance**	**Extra distance cost (1 km = Rs.200)**	**Total cost**
Transport Cost		67	71 km	35,000	21 km	4200	39,200
Insurance for Goods	1300	68					88,400
Other Expenses	3400						3400
Supporting Staff Service Salary	3*3500						10,500
Total Cost							141,500

Table 14 Cost of delivery cluster 05

Cluster 05							
Description	**Cost**	**QTY**	**Distance**	**Fixed cost**	**Extra distance**	**Extra distance cost (1 km = Rs.200)**	**Total cost**
Transport Cost		40	73 km	35,000	23 km	4600	39,600
Insurance for Goods	1300	40					52,000
Other Expenses	3400						3400
Supporting Staff Service Salary	3*3500						10,500
Total Cost							105,500

Table 15 Cost of delivery cluster 06

Cluster 06							
Description	**Cost**	**QTY**	**Distance**	**Fixed cost**	**Extra distance**	**Extra distance cost (1 km = Rs.200)**	**Total cost**
Transport Cost		76	19.5	35,000	0	0	35,000
Insurance for Goods	1300	76					98,800
Other Expenses	3400						3400
Supporting Staff Service Salary	3*3500						10,500
Total Cost							147,700

Table 16 Labor cost difference between labors in existing system and proposed system

	Salary	**Existing system**		**Proposed system**	
		Number of employees	**Total Cost**	**number of employees**	**Total Cost**
Area Manager	85,000	2	170,000	1	85,000
Warehouse Manager	80,000			1	80,000
Accountant	70,000	2	140,000	1	70,000
Assistant Accountant	55,000	2	110,000	1	55,000
IT Officer	50,000	2	100,000	1	50,000
Logistics Officer	50,000	2	100,000	1	50,000
Assistant Logistics Officer	35,000	4	140,000	2	70,000
Clark	20,000	2	40,000	3	60,000
sales ref	30,000	18	540,000	6	180,000
Forklift Drivers	28,000	9	252,000	3	84,000
Porters	25,000	27	675,000	15	375,000
Store Porters	25,000	9	225,000	4	100,000
Driver	32,000	10	320,000		0
Total		89	2,812,000	39	1,259,000

The overall transportation, warehouse operating, and administrative costs of the proposed system are listed in Table 18.

The monthly cost difference between the two methods is seen in Tables 17 and 18. The ABC Company determines all costs, including power, water, and total kilometers

Table 17 Total monthly cost of existing system

Destription	Total cost	Total Cost per Week	Total Cost per Month
Total Transportation Cost for Argent Point to Retail Market	11*12,500 = 137,500	137,500	550,000
Total Lorry	11		
Total cubic volume capacity per week	123		
Lorry Insurance	11*4190 = 46,090	46,090	184,360
Insurance of Goods (per cubic volume)	123*1300 = 1,562,100	159,900	639,600
Total Safety Stock Cost			87,000
Transportation Cost of Goods delivery from CWH to Argent Points		87,500	350,000
Salaries & Wages			2,812,000
Total Cost Per Month			Rs. 4,535,960

Table 18 Monthly cost of proposed system

Description	Cost value
Total Distribution Cost	832,000
Warehouse Rent Cost	600,000
Holding Cost	240,000
Total Salaries Cost & Wages	1,259,000
Electricity	45,000
Water	8500
Total Cost	Rs. 2,984,500

Table 19 A comparative study of the existing method and prosed method

Total Transportation, Warehouse Operation and Administration Cost for Existing System	Rs. 4,535,960.00
Total Transportation, Warehouse Operation and Administration Cost for Proposed System	Rs. 2,984,500.00
Total Cost saving through new heuristic compared to the Existing Model	Rs. 1,551,460.00 (34.2%)

traveled. The existing system costs Rs. 4,535,960 in total, while the proposed system costs Rs. 2,984,500. The suggested systems will save Rs. 1,551,460 per month and are 34% more efficient than the current ones. The Table 19 that follow present a comparison between the existing approach and the suggested method.

Conclusion and recommendation

Based on secondary data from SAP and distributor operation data from ABC Company, we built a central warehousing strategy. Gampaha and the Colombo region have been segmented into 26 demand regions. Each point's demand value has been determined. The gravity model (Andersson 1979) is used to determine the location of the new central warehouse after discovering the locations of each of the demand points (latitude and longitude). It is situated at the west side of Peliyagoda at latitude 6.954871182 and longitude 79.91259064. The main goal of this research is to develop a new model for lowering total transportation, warehouse, and administration costs.

All demand points in the Colombo and Gampaha Districts are grouped into six primary clusters, with an ideal path inside each sub-cluster, according to the heuristic procedure approach for a given site. Trucks are utilized to redistribute items that have been allotted along each of the best routes. The position of the central warehouse is determined using the gravity model (Andersson 1979), and all demand sites in the Colombo and Gampaha regions are grouped into six clusters using the proposed algorithms. Each sub-cluster has an optimal path that has been calculated. Finally, the distance was calculated using this new mathematical model to determine an optimal distance truck allocation method. According to the heuristic approach, products should be delivered to Colombo and Gampaha using six different route plans. The vehicle that delivered the supplies has a capacity of 77 cubic meters.

Items are delivered once a week under the current system, but with the new truck allocation mechanism, it is conceivable to convey enough goods once a month. 89 employees' ability was used in the distribution process under the present system, and they were given a salary of Rs. 2,812,000. The distribution process will be based solely on a central warehouse under the proposed approach, lowering the number of staff to 39 and salaries to Rs. 1,259,000. The entire transportation, warehouse operating, and administrative costs of the proposed system are Rs. 4,535,960 in the existing system. However, the identical process costs Rs 2,983,500 in the current system. When compared to the existing method, the proposed solution can save up to Rs 1,551,460 (34.2%).

In this paper, the customers are clustered around single depot. However, clustering customers around multi-depot may produce enriched result. Besides, a web-based Application modeling technique would be vital to solve large sized multi-depot VRP. Thus, we devote ourselves in these direction of future research.

Abbreviations
VRP: Vehicle routing problem; FMCG: Fast-moving consumer goods; SKU: Stock-Keeping Units; SAP: Systems, applications and products.

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Authors' contributions
DGNDJ: Conceptualization, Methodology, Analysis, writing the original draft. GHJL: Supervision, Writing-review and editing, Formal analysis. ZAMSJ: Supervision, Writing-review & editing, Visualization, Formal analysis. All authors read and approved the final manuscript.

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Declarations

Competing interests
The authors declare that they have no competing interests.

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