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An Intelligent Cost-Optimized Warehouse and Redistribution Root Plan with Truck Allocation System; Evidence From Sri Lanka

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Abstract

This study is a case study based on C.W. Mackie (Pvt), which is a well-known FMCG products organization in Sri Lanka. The company's outbound logistics has been considered in this research and it is mainly focused on the redistribution process in Sri Lanka. Extra routing costs due to unreasonable consumption of additional distance have been noticed in the current redistribution process. Our objective is to minimize the warehouse operation, administration and transportation costs by imposing constraints on the capacity and the volume. Here this problem is modeled as a variant of the vehicle routing problem with a heterogeneous vehicle fleet. To find the best locations for the depots, the K-Mean clustering method and new heuristic solution procedures to the problem are presented. A proposed heuristic algorithm has been used to find the optimal path between clusters. Multi depot capacity plan, cost comparison of the existing model and proposed model including Transport cost and salaries and wages of employees have been embedded to this research. Finally, the author has compared the total cost of multi-depot redistribution while proving huge cost benefits 21.3 % than the existing distribution method.

Keywords: Vehicle routing problem, heterogeneous vehicle fleet, decentralized distribution, heuristics

1. Introduction

In Sri Lanka, demand for C.W. Mackie has a volatile market and is rising steadily. Since these demands have four variables. Some variables are social, cultural, seasonal, and environmental. Patterns of demand vary from clauses to provisions. In the FMCG market, maintaining a high quality of service brings a 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. Some businesses outsourced their outbound operation to third-party logistics providers due to some challenges in the outbound supply chain. The shipping costs, capital costs, and risks, etc can be reduced by outsourcing.

Including Sunquick, Scan Jumbo peanuts, KotagalaKahata tea, Scan drinking water, N-joy Coconut oil, and Star Essences, the company has 47 stock keeping units (SKU). Nine distributors are active in the region of Colombo and Gampaha and 10 redistribution trucks are involved in the redistribution operation. The locations of such distributors are Kadawatha, Dehiwala, Malabe, Homagama, Piliyandala, Yakkala, Negambo, Gampaha and Angoda.

In modern trade, most companies use their representatives' distributors to reach clients. The key element involved in the cooperation and coordination of supply and demand with both the company and the customer is the distributors. This situation appears to give agencies more value and businesses have to pay more for their distributors. Even so, corporations have lost visibility between their supply chain's upstream and downstream partners. To mitigate this issue, this study suggests a method for the C.W. Mackie Company Sri Lanka to implement a self-owned and direct distribution route plan within its outbound logistics role in the regions of Colombo and Gampaha. An intelligent, fast, reliable, and interconnected logistics system should be used to maintain the two key aspects above. Because logistics is represented the image of the company and generally it is maintaining service level and to increase service level there must be a keen system. C.W. Mackie Logistics can be divided into two sectors. Those are Inbound Logistics and Outbound Logistics. Under Inbound Logistics, procurement, including imports, can be classified. The task of the procurement department is to buy products and raw materials from domestic and foreign suppliers, select suppliers, Sunqucik import, Scan Range and, etc. The distribution process in C.W. Mackie is depicted in Figure 1.

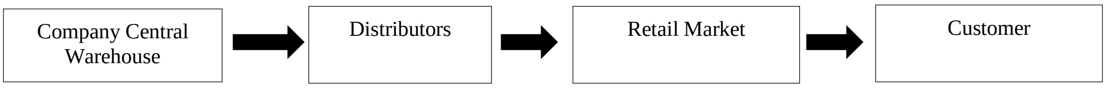

Figure 1:C.W. Mackie existing mode of distribution

1.1 Existing Company Structure

C.W. Mackie Company used a decentralized distribution strategy and Company has 9 consignment distributors in Colombo and Gampaha. Those 9 agents cover all outlets in Colombo and Gampaha. C.W. Mackie operates 10 vehicles for the redistribution process in Colombo and Gampaha.

1.2 Research Question

How to develop an innovative multi-depot approach for distribution of FMCG products using redistribution of vehicles in Sri Lanka with a minimal total cost of transportation, warehouse operation, and administration cost?

1.3 Description of Data

This research has been used secondary data from the SAP ERP system and other data collected from the agent operation database system. As an example, monthly target demand, Annual actual Demand, Annual demand quantity, and all the charges of each distributor, etc. this research has considered only one year.

1.4 Significance of the research

The concept of Distribution and Redistribution concept is strong in the outbound supply chain of the executives. For instance, redistribution shows organization image and market stability. In this manner, it should be under powerful procedure since it is a key factor in keeping up the administration level. The truck allocating process is very important in this regard. Therefore, there should be a truck allocation process that should while reducing the cost of transportation with maintaining a higher service level. Trucks' limited usage straightforwardly impacts the benefit of the business. If priority is not given to the redistribution process, the total supply chain will break up. Currently, C.W. Makie works are utilizing decentralized dissemination procedures in Colombo and Gampaha district using 9 distributors.
Through this, Multi depot distribution strategy will help to

- Determine ideal Multi depot warehouse locations
- Smooth redistribution root plan
- Cost-optimized redistribution vehicle allocation system

The outline of the paper is as follows. Section 2 summarizes the related works. Assumptions and notations are presented in section 3. Section 4 describes the problem statements, model formulation, and new heuristics method proposed along with the existing method and its shortcomings. Comparative assessments are performed in section 5. Finally, the conclusion and recommendation are drawn in section 6.

2. Related works

Finding the best routes for fleets to reach their customers has been the major focus of VRP – Vehicle Routing Problem which involves calculating the lowest cost delivery directions or paths from a depot to a set of geographically dispersed clients in a crosswise manner (Jayarathna et al., 2019, Jayarathna et al., 2020, Jayarathna et al., 2021, Ganepola et al., 2018). Multi Depot Vehicle Routing Problem (MDVRPs) is an expansion of classic style VRP with more than one depot, pertinent to associations that have a few branches and each branch pointed toward transport goods or administrations to their clients at the same time. The MDVRP can be viewed as an issue of clustering since its creation is a cluster of vehicle plans grouped by the stop. This depiction involves a methodology of grouping clients and booking the vehicles over each cluster. MDVRP is more testing and convoluted than single-stop VRPs (Aminu&Nura, 2021) & (Oliveira et al., 2015).

The Vehicle Routing Problem (VRPs) expands on the Travelling Salesperson Problem (TSP) with the addition of the bases, from which the traveling vehicles have to start and return to situations from the real-life issues that have led to the numerous variations of this simple concept. Various approaches that use modern and recently introduced algorithms are described (Braekers et al., 2015, Jayarathna et al., 2019). The vehicle routing problem mostly includes various Real-world constraints. All those constraints have to be taken into consideration when creating a feasible solution for real-world usage; the most famous constraints are time windows. MDVRPs all the while deciding the courses for a few vehicles from numerous stops to a cluster of clients and gets back to the same stop (Surekha&Sumathi, 2011, Jayarathna et al., 2021). It is a notable advancement issue with numerous genuine applications in the territories of transportation, dissemination, and coordination (Contardo&Martinelli, 2014). This research in enhancement prompted the improvement of various procedures for taking care of enhancement issues, for example, TSP, MDVRP, and other related enhancement issues (Aminu&Nura, 2021). Advancement measure is typically guided by Optimization Search Techniques; these methods are intended to give the best estimations of framework plan. Values that will prompt the most elevated levels of framework execution (Contardo&Martinelli, 2014).

The vehicle steering issue (VRP) has been an open issue and the essence of operational examination and combinatorial streamlining. As a variation of VRP, the multi-stop vehicle directing issue (MDVRP) has moreover pulled in more prominent interest from researchers (Braekers et al., 2015&Jayarathna et al., 2020) introduced a versatile information-driven imaginative particular methodology for addressing this present reality vehicle steering issues (VRPs) in the field of coordination. The work comprises of two fundamental units: (I) an inventive multi-step calculation for fruitful and possible addressing of the VRPs in coordinations what's more, (ii) a versatile methodology for changing and setting up boundaries and constants of the proposed calculation. (Li et al., 2019) utilized Ant Colony Optimization (ACO) to decide the arrangement of MDVRP variations, for example, MDVRP with different destinations and MDVRP with time windows. (Alinaghian&Shokouhi, 2018) created a composite calculation made out of a versatile enormous neighborhood search and variable area search to take care of this issue in which the heap space of every vehicle has a few areas, and each segment is devoted to a specific sort of made merchandise. The MDVRP issue is to dole out clients with the interest to every station under the condition that the inventory of every terminal isn't be surpassed, what's more, orchestrate the request wherein clients are visited by vehicles. The goal of the MDVRP is to limit the all-out course length and the number of vehicles. At MDVRP, the number and area of the terminal have been resolved ahead of time. Every stop has surely huge enough to oblige orders from clients.

2.1 K – Mean Clustering method

The vehicle routing problem mostly includes various Real-world constraints. (Li et al., 2016). All those constraints have to be taken into consideration when creating a feasible solution for real-world usage; the most famous constraints are time windows (Hastie et al., 2000). The method introduced in this instructional exercise, k-mean clustering has a place with apportioning-based strategies gathering, which depends on the iterative migration of information focuses between groups. It is utilized to separate either the cases or the factors of a dataset into non-covering gatherings, or bunches, in light of the qualities revealed. (Hastie et al., 2000) Regardless of whether the calculation is applied to the cases, or the factors of the dataset rely upon which measurements of this dataset we need to lessen the dimensionality of. The objective is to create gatherings of cases/factors with a serious level of comparability inside each gathering and a low level of likeness between gatherings (Hastie et al., 2001).

The k-mean clustering strategy can likewise be depicted as a centroid model as one vector addressing the mean is utilized to portray each group. (MacQueen, 1967), the maker of one of the k-mean calculations introduced in this paper, considered the fundamental utilization of k-mean clustering to be all the more a route for analysts to acquire subjective and quantitative understanding into huge multivariate informational collections than an approach to locate an exceptional and authoritative gathering for the information. K–Mean clustering is exceptionally valuable in exploratory information investigation and information mining in any field of examination, and as the development in PC power has been trailed by a development in the event of enormous informational collections. Its simplicity of execution, computational productivity, and low memory utilization have kept the k-implies grouping mainstream, even contrasted with other clustering methods. Such other grouping strategies incorporate network models like progressive clustering techniques (Hastie et al., 2000). These have the benefit of taking into consideration an obscure number of groups to be looked for in the information, however are expensive computationally because of the way that they depend on the disparity framework. Likewise remembered for bunch examination strategies are conveyance models like assumption amplification calculations and thickness models (Ankerst et al., 1999). An optional objective of k-Mean clustering is the decrease of the complexity of the information. The mathematical evaluations are bunched into the letters and addressed by the normal 16 remembered for each class. At last, k-mean clustering can likewise be utilized as an instatement venture for all the more computationally costly calculations like Learning Vector Quantization or Gaussian Mixtures, in this way giving an estimated division of the information as a beginning stage and diminishing the commotion present in the dataset (Shannon, 1948 , Li et al., 2016)

3. Assumptions and notations

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

3.1 Assumptions.

1) Google map is used to find distance between two demand points in Colombo region.
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 factor, driver’s behaviour, individual condition of 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) Rapid change in demand is not allowed.
6) Reverse logistics is allowed as soon as goods are handed over to the outlet, empty bottles are equivalent to delivered filled bottles and reverse logistics has no influence on this research.
7) There is no barrier in delivering goods.
8) Allocated truck in a cluster deliver goods within the cluster only. None of the trucks travel between two distinct clusters.

3.2 Notation

The notations associated with the development of our model are listed as follows:

3.2.1 Decision variables

R = Total number of depots arranged in the method;
n_i= Number of demand points in the i^th depot;
n = Total number of demand points in the distribution;

3.2.2 Other parameters

Parameters for calculate Transportation Cost (Fuel and Maintenance cost)
G= (V, E) , a graph of logistics distribution network;
$V=\{V_i / i \in \{1,2,3 \ldots \ldots . . n\}\}$, set of nodes/vertices;
E □{(i, j) | i, j∈V,i□□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;
$d_{V_j V_k}^{ir}$ = Distance traveled from client V_j to client V_k in the r^{th} cluster at i^{th} depot; (Here $d_{V_j V_k}^{ir} = d_{V_k V_j}^{ir}$)

d_{ir} = Total distance traveled in the r^{th} cluster at i^{th} depot;
d_i= Distance travel in thei^{th}depot vehicle;
d = Total distance travel through all clusters 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 maintance cost coeffient ration for a vehicle used in r^{th} cluster at i^{th} depot;
F_{ir} = Unit distance fuel cost coeffient ratio for a vehicle used in the 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 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,

3.2.3 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 i^{th} depot;
S_i = Budgeted Salary of the i^{th} depot
MW_i = Budgeted rental cost of the i^{th} depot
AE_i = Budgeted Additional cost of the i^{th} depot
S_p^i = Salary of the p^{th} position employee at the i^{th} depot; where $i \in \{1,2,3 \dots \dots . . R\}$, $p \in \{1,2,3 \dots \dots . . P\}$

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

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

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

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

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

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

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

TWOA = Total cost for Warehouse Operation and Administration
WOC = Warehouse and Operation Cost
TTC = Total Transportation Cost

TTWOA = Total cost for Transportation, Warehouse Operation and Administration

4. Problem statement and model formulation

4.1 Problem statement

This study focused on C.W. Mackie (Pvt), which is a renowned FMCG company, and the outbound logistics of a company, was considered and it is mainly focus in the region of Colombo and Gampaha on the distribution and redistribution process and the current decentralized redistribution process, Additional routing costs have been noted due to unreasonable consumption of additional distances. So company suffers with an extra transportation and warehouse cost in this system due to covered redundant distances generated by improper utilization of the used Lorries. So, the senior management of the company wants to carry out a further investigation in order to minimize the additional transportation, warehouse operation and administration cost incurred in the city area. Our endeavor here is in this direction.

The Problem is defined as a completed directed graph G = (V, A), where a tour of each cluster finishes at destination node $V_0, (V_0 = V_{n+1})$. We plan to find an optimal number of clusters in such a way that minimizes the total distance traveled considering all clusters, along with the total number of vehicles and relavant clients for each of the clusters. Let a depot is ready to provide products for a fleet Dvehicles with capacity Q_i,, where $i \in \{1,2,3 \dots \dots . . D\}$. Our intention here is to introduce method to minimize the said transportation, warehouse operation and administration cost. The nodes excluding the central one represent geographically spreaded customers. Each customer $i \in V - \{V_0\}$ has certain positive demand such that $\sum_{j=1}^{n_i} (q_j^i) \leq Q_i$. The distance matrix is symmetric, since $d^i_{V_j V_k} = d^i_{V_k V_j}$ for all $j, k \in \{0,1,2,3 \dots \dots . . n_i\}$,$i \in \{1,2,3 \dots \dots . . D\}$,$i \neq j$. The main distributiondepots arrange the transportation facilities to the vehicles. That is, the distribution center organizes each of the vehicles with the transportation plan and the corresponding routing. 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 completion of its tasks. Thus, a distribution depot has to arrange transportation routing in such a way that minimizes the total tansportation cost of the whole system by taking those costs into account.

There exists a research gap between the existing VRP's and our proposed new model in this paper. Our proposed model is new in the sense that we include the fuel consumption costs maintenance cost, warehouse operation cost and administration cost, which are essential to transportation practice in the new perspective of coordinating the economic cost. The solution to the model consists of designing optimal delivery and pickup routes: (1) starting and ending at the Depot, (2) visiting each customer exactly once, (3) satisfaction to all demands. The total cost is equal to the sum of fuel cost, maintenance cost of vehicles, warehouse operation cost and administration cost.

4.2 The model formulation

This section considers a transportation system of FMCGproducts from a multi-depot using a group of vehicles. The distribution depots organize each vehicle with a transportation plan along with a routing. A vehicle starts its route from the distribution depot and return 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 demand. 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 during completing its tasks. Thus, the central depot has to arrange transportation routing in a way that minimizes the total transportation, warehouse operation, administration Costs of the whole system by taking those costs into account. Thus, our proposed MDVRP 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 the transportation practice in the perspective of coordinating the economic cost. Here, the fuel consumption cost mainly comprises of the oil cost and the usage cost (measured by the time consumed and mainly includes the depreciation cost, the operators' salaries, the insurance expenses, etc.).This research is based on the existing Decentralized Distribution Strategy with maintaining nine distributor points and proposing a new Multi Depot Centralized distribution Strategy. Figure 2below shows the Conceptual frame work.

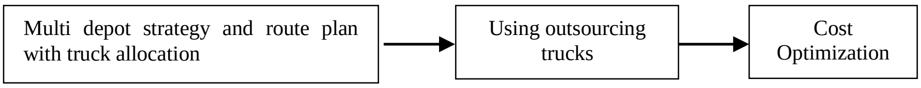

Figure 2: Conceptual frame work

4.2.1 Identification of optimal number of new warehouse locations by using the improved K- means clustering

We use the existing K- means clustering method and according to our proposed method we add some adjustments as given below. It helps to identify the optimal number of warehouse locations for the demand distribution. Steps of the process can summarize as follows.

4.2.1.1 Introduce the Improved k – Means clustering method

Step 01: Assigning all set of demand points x_1, x_2,…… x_n , σ^2 value to the system and assuming number of Depots (K)
Step 02: Find google location C_1, C_2,…… $C_k$for all k depots (Initial guess for depots)
If (assign demand points changed from relevant depot)
Step 03: Find nearest depot$C_j$for each point x_i (Through D (x_i, C_j))
Step 04: Assign the point x_i to depotC_j for each point x_i
Step 05: Use C_j (a) = $\frac{1}{n_j}\sum_{x_i \to C_j} x_i(a)$ formula to find new google locations of new depot C_j , where j = 1,2,3,……..K
New DepotC_j = mean of all points x_i assigned to depot j in the previous step
Else
Step 06: Stop the process
Step 07: Find min R ($\left|\sum_{i=1}^{R}\sum_{r=1}^{n_i}(x_r - c_i)^2\right| < \sigma^2$)

4.2.1.2. Use Gravity model calculations to complete the Improved k – Means clustering method

We use the gravity model as given below from (Andersson ,1979)to identify the exact location of central warehouse,

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

n, the number of demand points (1,2,3……..,n)
(x_i, y_i), the given location coordinates with the i^{th}demand point (latitude & longitude)
d_i, the demand associated with the i^{th}demand point.
(X, Y), the unknown location coordinate of the new warehouse facility

4.2.2 Introduce new heuristic method to cluster analysis on depot

We have developed heuristic method for clustering and introduced new mathematical model to calculate Total Transportation, Warehouse Operation and Administration Cost to solve the time-dependent vehicle routing problem. First, we form the clusters of clients based on the vehicle capacity and demand of each of the clients. 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.

Heuristic 1

This heuristic procedure can be described as follows: Initially, following the gravity model formulae proposed by Andersson (1979)we find the optimal location for the central depot (V_0). Then from the pool of clients (or n demand points) identify the nearby client (V_1) to the central depot. This can be done by taking the minimal value of the distances from the central depot to each of the clients in the distribution. Thereafter, from the remaining n-1 number of clients, identify the next nearby client (V_2) to V_1. This can also be done by taking the minimal value of the distances from $V_1$to each of the remaining n-1 number of clients in the distribution. In order to see whether V_2belongs to the same cluster containing V_1, compare the distances of V_2 from both V_0 and V_1 denoted mathematically as $d_{V_0V_2}$ and $d_{V_1V_2}$ respectively. If $d_{V_0V_2} \geq d_{V_1V_2}$ then both $V_1$and V_2 belongs to the same cluster.

Otherwise, V_1 and V_2 do not belong to the same cluster. Next, , V_1 and V_2 belong to the cluster, then identify the next nearby client (V_3) to V_2 from the remaining n-2 number of clients. If $d_{V_0V_3} \geq d_{V_2V_3}$ then V_3 belongs to cluster that contains V_2. Otherwise, V_3does not belong to that uster. On the other hand, if V_2 does not belong to the cluster that contains V_1, then from the remaining n-2 number of clients, identify the next nearby client (V_3) to V_1. If $d_{V_0V_3} \geq d_{V_1V_3}$, then V_3 belongs to cluster that contains V_1. Otherwise, V_3does not belong to the cluster that contain V_1. Likewise we will continue the same process and identify the first cluster (containing V_1). Then, by using the cost formulae (1) we will calculate the total cost of fuel and maintenance of the first cluster. This process will continue to form clusters containing $V_2, V_3, \ldots$ until all the clients in the distribution are filtered into clusters.

Based on this notion, the following algorithm is developed to form clusters of clients in a distribution.

Algorithm 1

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.

4.2.3 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 r[th] cluster vehicle at i[th] depot ;

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

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

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

where $r \in \{1,2,3 \ldots\ldots.. C_i\}$, $i \in \{1,2,3 \ldots\ldots.. R\}$,[1]

$$d_{ir} = \sum_{j=0, j \neq k}^{n_r^i} \min(d_{V_jV_k}^{ir}), \text{where } i \in \{1,2,3 \ldots. R\} \text{ and } j, k \in \{0,1,2,3 \ldots\ldots.. n_r^i\},\ V_0^i = V_{n_{i,}+1}^i$$

, distance travel in the r^{th} cluster vehicle at i^{th} depot vehicle which Each tour start from V_0^i and end on $V_{n_{i,}+1}^i$

$$d_i = \sum_{i=1}^{R} (d_{ir}) \text{ , where } r \in \{1,2,3 \ldots\ldots.. C_i\}, i \in \{1,2,3 \ldots\ldots.. R\} \text{, distance travel in the} i^{th}$$

depot vehicle

$$d = \sum_{i=1}^{R}(d_i) \text{ , where } r \in \{1,2,3 \dots\dots..C_i\} \ i \in \{1,2,3 \dots\dots..R\} \qquad [2]$$

$$\sum_{j=1}^{n_r^i}(q_j^{ir}) \le Q_{i,r} \text{ , where } r \in \{1,2,3 \dots\dots..C_i\}, \quad i \in \{1,2,3 \dots\dots..R\}, \qquad [3]$$

Consraint (3) ensures that the total demand arises in the r^{th} cluster vehicle at i^{th} depot can not exceed the vehicle capacity.

$$n_i = \sum_{r=1}^{C_i}(n_r^i) \text{ , where } r \in \{1,2,3 \dots\dots..C_i\}, i \in \{1,2,3 \dots\dots..R\} \qquad [4]$$

$$n = \sum_{i=1}^{R}(n_i) \text{ , where } \quad i \in \{1,2,3 \dots\dots..R\}, \qquad [5]$$

$$n = \sum_{i=1}^{R}\sum_{r=1}^{C_i} n_r^i \text{ , where } r \in \{1,2,3 \dots\dots..C_i\}, i \in \{1,2,3 \dots\dots..R\} \qquad [6]$$

$$d_{V_jV_k}^{ir} + d_{V_kV_l}^{ir} \ge d_{V_jV_l}^{ir} \text{ for all } j,k,l \in \{0,1,2,3 \dots\dots..n_i\} \qquad [7]$$

The distance matrix is symmetric, i.e.

$$d_{V_jV_k}^{ir} = d_{V_kV_j}^{ir} \text{ for all } j, k \in \{0,1,2,3 \dots\dots..n_r^i\}, i \in \{1,2,3 \dots\dots..R\}, i \neq j \qquad [8]$$

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 system but can be used for single depot to do all cost calculations.

Finding an optimal solution to this model is a comprehensive task that requires a great amount of time for calculation ([1]). However, this type of models has economic value especially when it associated with an integrated supply chain management. As a result, many logistics solution providers have emerged to cater to this rising demand, and these custom-made solutions are highly paid by companies. At the same time, 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.

4.2.4. Calculation of the Total Warehouse Operation and Administration Cost

TWOA = AC + WOC

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

$$AC = \sum_{i=1}^{R}\sum_{p=1}^{P} X_p^i * S_p^i \text{ , where } i \in \{1,2,3 \dots\dots..R\}, p \in \{1,2,3 \dots\dots..P\}$$

$$WOC \quad \sum_{i=1}^{R}[W_i + \sum_{l=1}^{L} Y_l^i * E_l^I , + \sum_{m=1}^{M}\sum_{r=1}^{C_i}(Z_{mr}^i * VAC_{mr}^i) + \sum_{n=1}^{N} XE_n^i * AE_n^i], \text{ where } i \in \{1,2,3 \dots\dots..R\} =, \quad p \in \{1,2,3 \dots\dots..P\}, l \in \{1,2,3 \dots\dots..L\}, n \in \{1,2,3 \dots\dots..N\}$$

4.2.5 Mathematical formulation to calculate the total transportation, warehouse operation and administration Cost

TTWOA = TTC + AC + WOC

$$TTWOA=\sum_{i=1}^{R}\sum_{r=1}^{C_i}\{AVV_{ir}^{t}\}*\{R_{ir}+F_{ir}\}\sum_{j=0\,,j\neq k}^{n_r^i}\min(d_{V_jV_k}^{ir})+\sum_{i=1}^{R}\sum_{p=1}^{P}X_p^i*S_p^i+\sum_{i=1}^{R}[W_i+\sum_{l=1}^{L}Y_l^i*E_l^i\,,+\sum_{m=1}^{M}\sum_{r=1}^{C_i}Z_{mr}^i*VAC_{mr}^i+\sum_{n=1}^{N}XE_n^i*AE_n^i\,]$$

$\sum_{k=1}^{P} X_k^i * S_k^i < S_i$, $i \in \{1,2,3 \ldots R\}$,/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 ;

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

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

5. Analysis of the Research

5.1 Route Analysis - Existing method

Here we introduce a current existing method arranged by C.W. Mackie (PLC) to calculate the transportation cost for a given distribution of demand points, which requires clustering of clients.For distribution, Company has used decentralized distribution strategies and Company has 9 consignment distributors in Colombo and Gampaha. Those 9 agents cover 5483 outlets in Colombo and Gampaha. C.W. Mackie operates 10 vehicles for Redistribution process in Colombo and Gampaha. Fig.3 below shows distributors in Colombo and Gampaha of C.W. Mackie Company.

Figure 3: Distributors of C.W. Mackie in Colombo and GampahaRegions.

Nine distributors are operating in the region of Colombo and Gampaha, including five distributors operating in the region of Colombo and four distributors in the region of Gampaha. The following Table 1 gives the annual sales of distributors in the Colombo and Gampaha area.

Table 1: 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

5.2 Use Improved K-Means clustering method to calculate optimal number of depots

To find an optimal location of distribution, main depots will allow the facility to deliver goods for clients with minimum transportation cost. From the pool of demand points, identify the number of optimal depots and their locations by considering their geographical situation.

Her research focus area is divided into 25 demand points. In the initial stage, all demand points are divided into three main central depots according to the geographical situation. First, we got the distance from those three locations to all demand points in the distributions. Miriswatta, Rathmalana, and Mulleriyawa are the three assumed locations for central depots. Once divided all demand points into three main depots, according to the second step of the K – Means Clustering technique researcher used the gravity model to find the new locations of three central depots of the distributions. In section 4 researcher already discussed the method of finding an optimal number of depots of the distribution and their locations. According to the said process, three locations are as follows. The first location is located at latitude 7.167594885 and longitude 79.93052059, which is situated nearby the Yatiyana. The second location is with latitude 6.825661878 and longitude 79.88689352, which is situated nearby the Rathmalana, and the last location is with latitude 6.940728802 and longitude 79.89687281, which is situated nearby the Welewatta.

5.3Using proposednew Algorithm for cluster analysis on depots

5.3.1 Cluster Analysis Based on Yatiyana Depot

As an example for the proposed new algorithm calculation table 2 is introduced. It shows the starting and ending towns of each of the sub tours of cluster 1 at Yatiyana Depot along with optimal distances travelled **(**Google distance**)** and the total distance traveled inside the cluster 1 (total milk run). Below table 2 shows the cluster 1 arrangement of Yatiyana Depot

Table 2: Arrangement of the Cluster 1- Yatiyana Depot

Route Analysis (Cluster 01 – Yatiyana Depot)				
Starting Town	**Ending Town**	**Cubic Volume**	**Distance Traveled (km)**	**Transshipment Node**
Yatiyana, East	Ja-Ela	5	13.8	No
Ja-Ela	Gampaha	15	16.5	Yes
Gampaha	Yakkala	8	3.7	Yes
Yakkala	Weliweriya	2	8.9	Yes
Weliweriya	Mirigama	12	34.4	Yes
Mirigama	Kochchikade	4	33.7	Yes
Kochchikade	Yatiyana, East	0	17.7	Yes
Total of Volume & Distance		**46**	**128.7km**	

The optimal path of cluster 1- (Yatiyana Depot) is shown in Fig. 4.

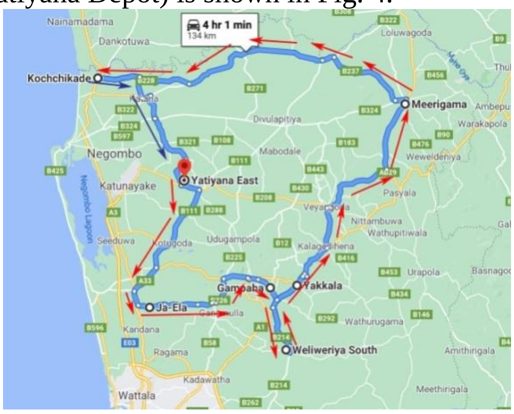

Fig.4: Optimal Path of Cluster 1 – Yatiyana Depot

Likewise, all the milk run of each cluster of three depots are found using proposed Algorithm and table 3 shows the results of calculations.

Table 3: Cluster arrangement of three depots

Depot	Cluster	Total travelled distance in cluster (Milk run) (km)	Total, cubic volume covered (m^3)
Yatiyana	Cluster 01	128	46
	Cluster 02	34.2	35
Rathmalana	Cluster 01	22.6	77
	Cluster 02	53.3	28
Welewatta	Cluster 01	42.5	75
	Cluster 02	12.4	72
	Cluster 03	43.7	58

5.4 Calculation the transportation cost of existing method

C.W. Mackie (Pvt) Ltd currently distributes FMCG products in Colombo and Gampaha from nine distributing centers. Below table 4 shows the cost of transporting goods under the existing system.

Table 4: Cost of transporting goods under the existing system

Description	Total cost	Total Cost per Week	Total Cost per Month
Total distribution Cost Argent Point to Retail Market	11*12500=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	123*1300=159,900	159,900	639,600
Total Safety Stock Cost			87,000
Transportation Cost of Goods delivery from Central warehouse to Argent Points		87,500	350,000
Salaries & Wages			2,812,000
Total Cost Per Month			Rs. 4,535,960

5.5 Calculation the total transportation cost of Propose method

In the current process, delivery is done once a week, but with the new system, delivery of goods is done using a truck, which means that the goods can be delivered once a month at a reduced cost, and the cost is born by the cluster as shown in the following cost tables for this are shown separately below. It also includes the cost of delivery, the cost of insuring goods, the cost of employee assistance, and the cost of others (cost of refreshment). Here the trucks take a fixed price within the first 50 kilometers and chargers to the 200 for the remaining extra a kilometer. The capacity of the prime mover (propose vehicle) delivering 77 cubic volume.

Table 5 shows the total optimal distance traveled in each of the two clusters relevant to Yatiyana Depot. Further total milk run under the propose method and finally total transportation cost of the Yatiyana Depot can be calculated.

Table 5: Total distance traveled in each of two clusters – YatiyanaDepot

Description	**Distance travelled**	**Fixed Transportation cost of the cluster**	**Additional distance travelled**	**Additional Transportation Cost (Rs. 200 Per One Kilo Meter)**
Cluster 01	128.7	35,000	78.7	15,400
Cluster 02	34.2	35,000	0	0
Total Distance travelled in Cluster (Km)	162.9			
Fixed Transportation Cost (Rs)	70,000			
Additional distance Transportation Cost (Rs)	15,740			
Total Transportation Cost of the Proposed System (Rs)	85,740			

Table 6 shows the total optimal milk run under the propose method and total transportation cost of the Rathmalana Depot.

Table 6: Total distance traveled in each of two clusters – Rathmalana depot

Description	**Distance Traveled**	**Fixed Transportation cost of the cluster**	**Additional distance travelled**	**Additional Transportation Cost (Rs. 200 Per One Kilo Meter)**
Cluster 01	22.6	35,000	0	0
Cluster 02	53.3	35,000	3.3	660
Total distance travelled in Cluster (Km)	75.9			
Fixed Transportation Cost (Rs)	70,000			
Additional distance Transportation Cost (Rs)	660			
Total Transportation Cost of the Proposed System (Rs)	70,660			

Table 7 shows the total optimal milk run under the propose method and total transportation cost of the Welewatta Depot.

Table 7: Total Distance traveled in each of three clusters – Welewatta depot

Description	**Distance Traveled**	**Fixed Transportation cost of the cluster**	**Additional distance travelled**	**Additional Transportation Cost (Rs. 200 Per One Kilo Meter)**
Cluster 01	42.5	35,000	0	0
Cluster 02	12.4	35,000	0	0
Cluster 03	43.7	35,000	0	0

Total Distance travelled in Cluster (Km)	**98.6**
Fixed Transportation Cost (Rs)	**105,000**
Additional distance Transportation Cost (Rs)	**0**
Total Transportation Cost of the Proposed System (Rs)	**105,000**

Table 8 shows the cost of delivery to Yatiyana depots and its included Insurance for goods other expenses and other staff service salaries.

Table 8: Total Insurance for Good, Other Expenses and Other Staff Service Salaries.

Depots	**Quantity Cubic Volume**	**Insurance for Goods**	**Total, Cost for Insurance Rs**	**Other Expenses Rs**	**Supporting Staff Service Salary(Rs)**	**Total, Cost Rs**
Yatiyana	81	1,300	105,300	3,400	7,000	115,700
Rathmalana	105	1,300	136,500	3,400	7,000	146,900
Welewatta	205	1,300	266,500	3,400	7,000	276,900
Total Cost for all three depots						800,900

Table 9 shows the rental cost of each warehouse.

Table 9: Warehouse Rent cost

	Yatiyana		**Rathmalana**		**Welewatta**	
	Quantity (SQF)	Cost (Rs)	Quantity (SQF)	Cost (Rs)	Quantity (SQF)	Cost (Rs)
Warehouse Rent	5500	250,000	7500	350,000	10000	375,000

5.6 Comparing Salaries and wages in the Current System and Propose System

The bellow 10 table provides the results of the new system and the existing system with employee analysis and wages.

Table 10: Labor Cost Difference between 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			3	240,000
Accountant	70,000	2	140,000	1	70,000
Assistant Accountant	55,000	2	110,000	2	110,000
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	6	168,000
Porters	25,000	27	675,000	6	150,000
Store Porters	25,000	9	225,000	3	75,000
Driver	32,000	10	320,000	0	0
Total		89	2,812,000	41	1,308,000

In the current system, it operates through the distribution center and does not need a warehouse manager. In the proposed system, the trucks are hired the driver, so in the second case, the driver does not have to pay a separate salary. Furthermore, the distribution of the existing system will take place through 9 distribution centers, where the number of employees will increase, but in the proposed system the distribution takes place only through the three (3) warehouses, resulting in a reduction in the number of employees. In the existing system, the total cost of salaries and wages is Rs 2,812,000, and the proposed system's total cost of salaries and wages is Rs 1,308,000.

5.7Total Cost Analysis of the existing system and proposed system.

The research is to determine new facility cost and compare it with the cost of the existing system. The bellow table 11 provides the total transportation, warehouse operation and administration cost of the existing system.

Table 11: Total Monthly Cost of Existing System

Description	**Total cost**	**Total Cost per Week**	**Total, Cost per Month (Rs)**
Total Transportation Cost for Argent Point to Retail Market	11*12500=137500	137500	**550000**
Total Lorry	11		
Total cubic volume capacity per week	123		
Lorry Insurance	11*4190=46090	46090	**184360**
Insurance of Goods (per cubic volume)	123*1300=1562100	159900	**639600**
Total Safety Stock Cost			87000
Transportation Cost of Goods delivery from CWH to Argent Points		87500	**350000**
Salaries & Wages			**2812000**
Total Cost Per Month			**4,535,960**

The bellow table 12 provides the total transportation, warehouse operation and administration Cost of the proposed system.

Table 12: Total transportation, warehouse operation and administration cost

Description	**Cost**
Total Distribution Cost	261,000
Warehouse Rent Cost	975,000
Holding Cost	125,000
Total Insurance for goods other expenses	800,900
Total Salaries Cost & Wages	1,308,000

Electricity	100,000
Total Cost	**Rs. 3,569,900**

The total cost of the existing system is Rs. 4,535,960 but the proposed system cost is Rs. 3,569,900. Proposed systems bring savings of Rs. 966,960 per month and it is 21.29 % savings compared to the existing system. Below table 13 shows the comparative study of the Existing method and Prosed method.

Table 13: A comparative study of the Existing method and Prosed method

Total Transportation, Warehouse Operation and Administration Cost for Existing System	**4,535,960**
Total Transportation, Warehouse Operation and Administration Cost for Proposed System	**3,569,900**
Total Cost saving through new heuristic compared to the Existing Model	**966,960 (21.29 %)**

6 . Conclusion and Recommendation

Based on secondary data collected from SAP and distributor operation data based in C.W. Mackie, here we developed a multi-depot strategy. Colombo and Gampaha regions have been divided into 25 demand points are identified. After finding the locations of each of the demand points (latitude and longitude), Improved K-Means Clustering Method with Gravity model (Andersson, 2011) has been used to identify the three best locations of the new depots. Three optimal depot locations are situated in Yatiyana, Rathmalana, and Welewatta. A further new heuristic algorithm has been used to find the optimal path between clusters on each depot. The Multi depot capacity plan, cost comparison of the existing model, and the proposed model including Transport cost and salaries, and wages of employed 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 large as 21.3 % as compared to the company's existing method. Multi Depot vehicle routing problem which is based on web-based Application modeling technique may be applied for better result of the currently studied problem in this paper. Future the research scope of the problem lies in this direction.

REFERENCE

[1] Alinaghian, M., Shokouhi, N. (2018). Multi-Depot Multi-Compartment Vehicle Routing Problem, Solved By A Hybrid Adaptive Large Neighbourhood Search. Omega, 76, 85–99.

[2] Aminu, A. M. & Nura, A. (2021).A Genetic Clustering Algorithm for Multi-Depot Vehicle Routing. SLU Journal of Science and Technology, 2(1), pp. 19–29.

[3] Anderson, J. E. (2011). The gravity model. Annual Review of Economics, 3,pp. 133–160. doi:10.1146/annurev-economics-111809-125114.

[4] Ankerst, M., Breunig, M.M., Kriegel, H. P. & Sander, J. (1999). OPTICS: Ordering points to identify the clustering structure. ACM Sigmod record, 28(2), 49-60.

[5] Braekers, K.,Ramaekers, K. & Nieuwenhuyse, I. (2015). The Vehicle Routing Problem: State of the Art Classification and Review. Computers & Industrial Engineering, 99. 10.1016/j.cie.2015.12.007.

[6] Contardo, C., Martinelli, R. (2014). A new exact algorithm for the multi-depot vehicle routing problem under capacity and route length constraints. International journal of Discrete Optimization, 12, 129-146. https://doi.org/10.1016/j.disopt.2014.03.001.

[7] Oliveira, D., Enayatifar, F.B., Sadaei., R., Guimarães, H.J. &Potvin, F.G.. (2015). A Cooperative Evolutionary Algorithm for the Multi-Depot Vehicle Routing Problem. Expert Syst. Appl. 43, 117–130.

[8] 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. doi:10.14254/jsdtl.2018.3-2.4.

[9] Hastie, T., Tibshirani, R. & Friedman, J. (2001). The Elements of Statistical Learning. Springer New York Inc. , New York, NY, USA .

[10] Jayarathna, N., Lanel, J., Juman, S. (2021). Survey on Ten Years of Multi-Depot Vehicle Routing Problems: Mathematical Models, Solution Methods and Real-Life Applications. International Journal of Sustainable Development Research, 3(1), https://doi.org/10.30560/sdr.v3n1p36

[11] Jayarathna, N., Lanel, J., &Juman, 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.

[12] Jayarathna, N., Lanel, J., Juman, S. (2019). A contemporary Recapitulation of Major Findings on Vehicle Routing Problems: Models and Methodologies. International Journal of Recent Technology and Engineering, 8(2S4), 581-585. https://doi.org/10.35940/ijrte.B1115.0782S419

[13] Li, Y., Soleimani, H. &Zohal, M. (2019) An improved ant colony optimization algorithm for the multi-depot green vehicle routing problem with multiple objectives. Journal of cleaner production., 227 (24), 1161–1172.

[14] Macqueen, J. (1967).Some methods for classification and analysis of multivariate observations. Berkeley Symposium on Mathematical Statistics and Probability, 5(1), 281-297.

[15] Surekha, S., Sumathi, P. (2011). Solution to multi-depot vehicle routing problem using genetic algorithms. World Applied Programming. 1,118-131.

[16] Shannon, C.E. (1948). A Mathematical Theory of Communication. Bell System Technical Journal, 27, 379-423. https://doi.org/10.1002/j.1538-7305.1948.tb01338.x