IJCTA, 9(10), 2016, pp. 4683-4693

Facility Location for Logistic Network Designusing Alternate Location Procedure and Minisum Location Allocation Method

***Shaju Varghese **Gladston Raj S**

Abstract : Logistic management is actually the process of locating an optimal location for providing the facility. The distribution centers (DCS) can be a place in village, beside of local roads, beside of main highways, or highly populated area in a city. So, it is necessary to find an optimal location to speed up the distribution and also to minimize the cost. It is clearly an important process to find optimal location for the DCs and also the number of DCs. The efficiency of the criteria adopted in this case will certainly affect the total performance. In this work it evaluated two linear methods known as ALA and minisum location allocation for facility location in logistics. In this work, itis going to find the optimum locations of DCs for logistic network design.

1. INTRODUCTION

The facility location analysis is the process identifying the location problem and generates a common model for finding the optimal location. This is nothing but identify k center problem, which deal with the optimal placement of facilities to minimize transportation costs by satisfying some constraints. The techniques also apply to cluster analysis so that the clustering algorithms used in data mining can also be applied for location analysis. In this work, we design a soft computing based model for facility location for logistics analysis.

Facility Location Problem(FLP)

Facility Location identification and allocation problem point to the solutions of finding the optimal/best solution to construct one or more facilities in order to attend the largest subset of users within a service distance. The facility location problem is a challenging and non-linear problem in the areas of production, procurement, distribution, operations management and combinatorial optimization. This problem is very popular because it is faced by majority of companies. A large number of researchers have studied this problem and proposed different approaches as solution.

Location models are difficult to solve, especially for large problem instances. There are many built in tools already in general facility location environment that overcome the critical computational complexity of a location models. Besides, location models are application dependent. Their objectives, constraints and variables are determined by particular problem under study. So, it is very difficult to develop a common model that can customize to a particular location model that is optimal for all potential or existing applications[3].

There are two types of techniques in general[3]

(*a*) Exact Solution Techniques[3]

(*b*) Heuristic Solution Techniques[3]

* Research Scholar, Bharathiar University, Coimbatore,Tamil Nadu, India

** Head of Department of CS, Govt. College, Nedumangadu , Thiruvananthapuram, Kerala, India. shajubpc@gmail.com, gladston@rediffmail.com

Applications of FLP

The research in this area has not only concentrated on the mathematical modeling and algorithmic aspects but also in the area of innovative applications. The applications include various optimization areas such as parameter calibration, land use optimization, transport route searching, retail shop outlet location selection, spatial objects optimization, performance optimization of urban modeling. When applied to telecommunication network design and capacity planning, the difficult task of designing and maintaining huge, reasonably optimal, telecommunication networks becomes more feasible. Many major telecommunication service providers are finding it imperative to upgrade or expand their facilities and services. The facility location models can make use of the design of various types of telecommunication networks.The capacitated optimization technique can play an important role for the improvement of the telecommunication network design. In this example,most of the analysis decisions have to be made concerning relation between concentrator location and cable expansion. Many analysts have claimed that more than 50% of capital and operating costs are a consequence of the provision of Local Access Telecommunication Networks (LATN).

The FLP and Logistics

Logistic

Logistic is a framework and it is essentially a planning orientation that seeks to create an efficient planning for the flow of products and required information through a business. The suppliers and customers co-ordinate and generate the logistic structure in supply chain management and seeks to achieve connectivity and co-ordinate between the processes of other events in the system. The functional nature of the logistics is dynamic and also depends on how and when one work area compare with the other. Since the logistics process is complex its functional performance measurement is tedious process.There are many important factors that will affect the internal co-ordination of the operational processes. They are support from the manufactures, material collection, space for the customer accommodation.

Optimization is the process of minimizing or maximizing the output of a well defined functions model. This problem tries to satisfy the fixed, presumably known demands of m customers by supplying each customer with the same commodity from a facility to be established at a particular site j. It is assumed that there are n candidate sites where facilities can be established if necessary. The unfortunate aspect of this very general class of mathematical programming problems is the fact that many of these problems have a high degree of complexity and general purpose algorithms to solve them dependably are not readily available.

Facility Network Design

The importance of facility location in overall network design for efficient business operation is not well defined in classical economics.In business management,the number, size, and geographical relationship of service providers used to perform logistical operations directly affect the customer service capability and cost. The examples of logistics facilities are production plants, stock rooms, retail distribution centers.

Logistics Network

A logistics network provides cost effective and efficient way of facilitates the distribution of packages. Multiple organizations can make use of this networked DCs for logistic management. The public Logistic Network (PLN) facility can improve the distribution performance with affordable cost. The distribution centers liked with this network and provide share the same to all the users connected to this network. Also this will act as the middle platform for the retailers and customers.

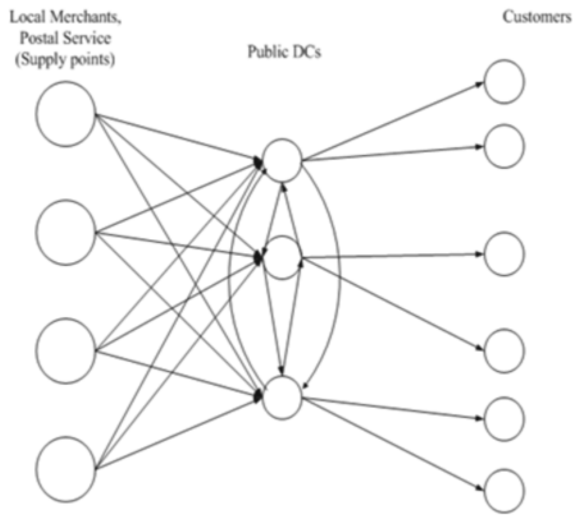

Fig. 1. The Package Flow in Logistics Network.

This PLN is working like an internet middle server. Like internet this system is also consider customer request and distribute the material as and when required. This is also owned by a firm or group of persons. Also individual persons having the freedom to establish the PLN and make it sharable with based on the request.

2. BACKGROUND ON FACILITY LOCATION AND ABOUT THIS WORK

Facility Location Problem

The main purpose of this procedure is to build a decision support system that helps the managers to decide where to locate a facility.

Alternate Location Allocation Procedure(ALA)

In location allocation problem, the ALAprocedure, provide optimal results in local improvement and thus is an effective procedure.

The heuristic procedures will examine various local minimum by changing more than one existing facilities(EFs). But, the ALA easily and quickly locate the local minimum from agiven set of starting locations for the NFs. So, the other heuristic procedures, that examine multiple local minimumcan utilize the solution found by the ALA method, have only been used to solve problems with less than 100 EFs and up to 10 NFs [14].

The ALA local improvement procedure was introduced by Cooper [9]. This ALA procedure will allocate the optimal locations for the existing facilities. This processstarting with NFs and find its initial optimal locations for these NF locations and then incorporate this solutions to find the optimal allocation of EFs. The intermediate NF locations for this allocation are then found. This process will continue with various allocation change until no further allocation changes are made. Locating the optimal allocations given the NFs locations corresponds to determining the NF closest to each EF. The algorithm starting by initializingany set of NF locations, themethod generates a sequence of locations and allocations which lead to a local minimum solution to the location-allocation problem, local minimum is defined as a set of locations and allocations such that the locations are optimal with respect to the allocations and the allocations are optimal with respect to the locations [12].

Lets consider the single facility location problem with 3 demand points that tries to minimize the sum of the squares of the Euclidean distances between the demand points and the facility. Let (ai, bi) be the coordinates of the demand points and (x, y) be the coordinates of the facility. Then the objective function we are trying to minimize is the following.

$$\text{minimize } f(x,y) = \left(\sqrt{(x-a_1)^2+(y-b_1)^2}\right)^2+\left(\sqrt{(x-a_2)^2+(y-b_2)^2}\right)^2 +\left(\sqrt{(x-a_3)^2+(y-b_3)^2}\right)^2$$

Obtain the point of minimum by taking the partial derivatives of $f(x, y)$ with respect to x and y, and setting partial derivatives to 0. This point of minimum is $(a1 + a2 + a3)/3$, $(b1 + b2 + b3)/3$, *i.e.* the average of the coordinates of the demand points. If we know the facility location, we can find the maximum distanced corner of each region to the facility by the following formula.

$$k_j^* = \arg\max_{k \in K_j} | S_j^k - x |$$

Then, the objective function of the single facility location problem takes the following simpler form

$$\text{minimize} \sum_{j=1}^{m} \| S_j^{k_j^*} - x \|^2$$

Minisum facility location

In a single facility location problem the criteria for placing the facility is to find all the weighted distance from the available set of points. Using this measurement it is possible to find the minimum weighted sum distance. In the case of multiple facilities that should included in the complex problems, constraints on the locations of facilities, and more complex optimization criteria.

Minisum Single Facility Formulation

$$\text{Min } f(x) = \sum_{i=1}^{m} w_i \times d(X, P_i)$$

where $X = (x, y)$: location of the new facility

$P_i = (a_i, b_i)$: location of the i-th existing facility, $i = 1, \ldots, m$

wi : weight associated to the i-th existing facility

Minimax Formulation :

$$\text{Min } f(x) = \text{Max } \{w_i \times d(X_i P_i)\} \Rightarrow \text{Min } z$$

$$s.\,t.\ w_i \times d(X_i P_i)\ z, \leq\ i = 1, \ldots, m$$

Minisum Multi-Facility Location Problem with Rectilinear Distances

Location of new facilities : $X_j = (x_j, y_j)$, $j = 1, \ldots, n$.

Location of existing facilities: $P_i = (a_i, b_i)$, $i = 1, \ldots, m$.

Weight between new facilities j and k: v_{jk}, where $k > j$.

Weight between new facility j and existing facility i: w_{ji}.

Problem formulation

$$\text{Min } f((x_1, y_1), \ldots, (x_n, y_n)) = f_1(x_1, \ldots, x_n) + f_2(y_1, \ldots, y_n)$$

Where

$$f_1(x_1, \ldots, x_n) = \sum_{1 \le j < k \le n} V_{jk} | X_j - X_k | + \sum_{j=1}^{n} \sum_{i=1}^{n} w_{ji} | x_i - a_i |$$

$$f_2(y_1, \ldots, y_n) = \sum_{1 \le j < k \le n} V_{jk} | y_j - y_k | + \sum_{j=1}^{n} \sum_{i=1}^{m} w_{ji} | y_j - b_i |$$

The Proposed Logistics Network Design

In Bansal [2], a Public Logistics Network (PLN) for the continental U.S. was designed. This research uses the same design approach that was developed by Bansal. Bansal's design can be explained as four step process that includes generation of the Underlying Road Network (URN), developing the network of public DCs, estimation of average package delivery time, and finding public DC locations that minimize average package delivery time.

In this work, the PLN will be designed using a similar process with some modifications and simplification in the steps. In this work, we use a simplified version of that design so that, instead of using the “average package delivery time” as a metric for optimization, we used simple distance as the metric in the fitness function of the soft computing model. This approach was used to minimize the optimization time. So, I believe that this approach also will lead to equal results, logically with in lesser time.

- Generation of the Underlying Road Network (URN)
- Developing the network of DCs,
- Finding public DC locations that minimize the distance between the DCs and the User locations.

Generation of the Road Network of USA

The following map shows the road network that we created from the US census data set.

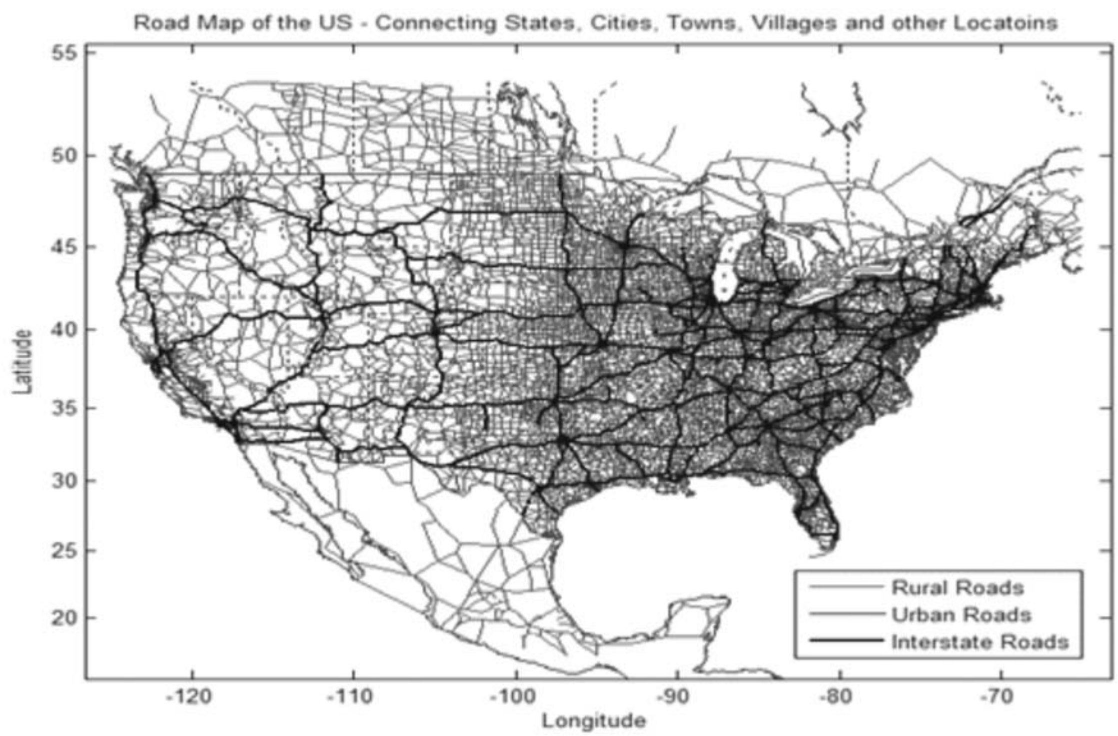

Fig. 2. Road Network of USA.

Generation of the Underlying Road Network of Regional Distribution Centers

The population in RDC is represented by total 925 U.S. census blocks that are plotted on the map of RDC. A sub-graph of the road network was generated that is then followed by the removal of two-degree nodes from the network. Each point in this network is a potential location for a DC.

The following graph/map shows the road network of Louisiana, USA that will be the example of a sub graph we created and used to create the regional distribution centers (RDC) that we are interested in.

Fig. 3. Underlying Road Network of RDCs

Network of DCs

If needed, we may also create the network of DCs as follows. The arcs connecting census blocks to the URN are added to the network and the shortest time paths and distances between each pair of points are calculated using Dijkstra's algorithm. DCs will be located at some of the key points and then connected to each other using Delaunay Triangulation [19] to form a network of public DCs. The shortest time paths between all pairs of DCs is found and those paths and distances are then used to calculate the percent flow of the packages, wij from DC i to DC j using order based proximity factors developed by Kay and Parlikad [1] using following equations.

In this work, we use ALA and Minisum methods to find optimum location of DCs based on the local distance between the DCs and the User locations.

Map : Alabama, USA

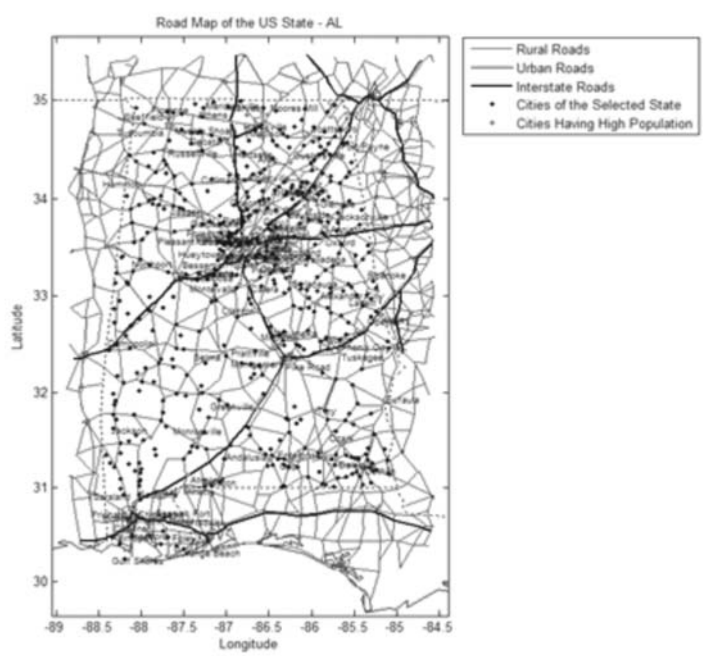

Fig. 4.

Random Initial Locations of DCs

The Initial Average Distance between DCs and Customer Locations: 9.44 Units

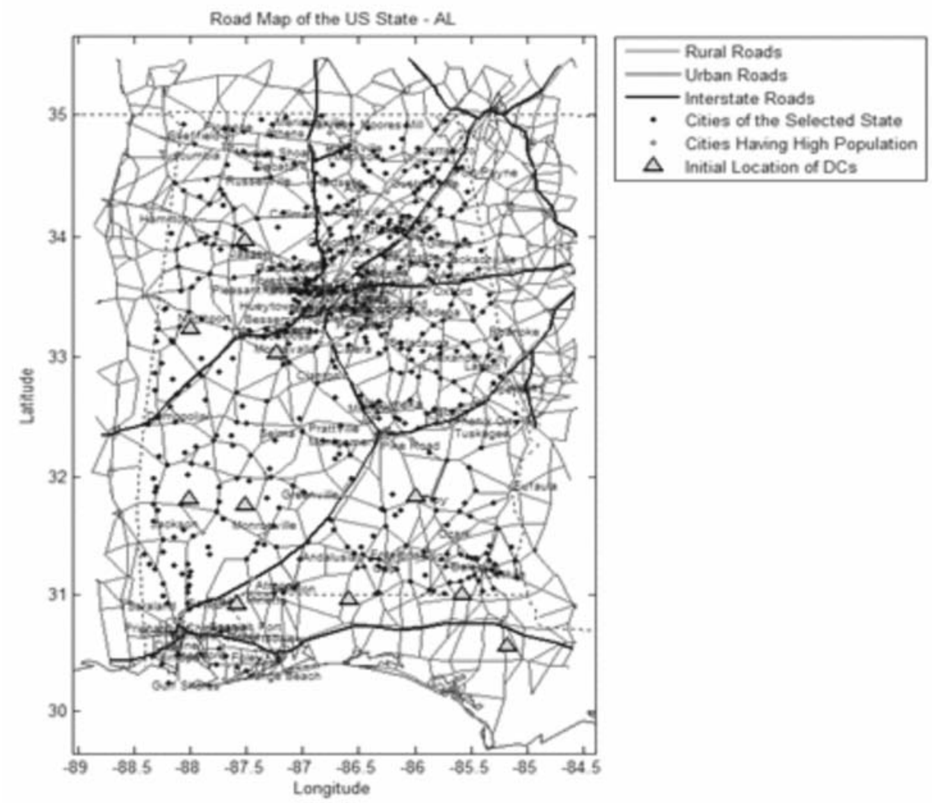

Fig. 5.

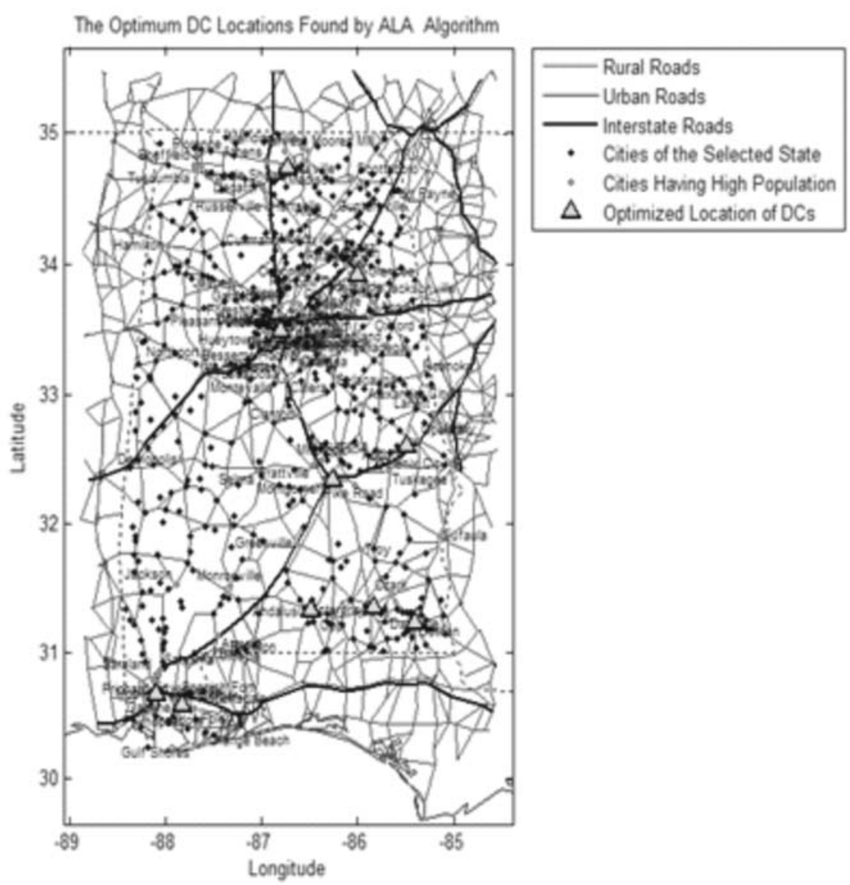

Fig. 6. The Average Distance between DCs and Customer.

Locations: 4.68 Units

The Time Taken for Finding Optimum Locations of DCs

2.86 seconds

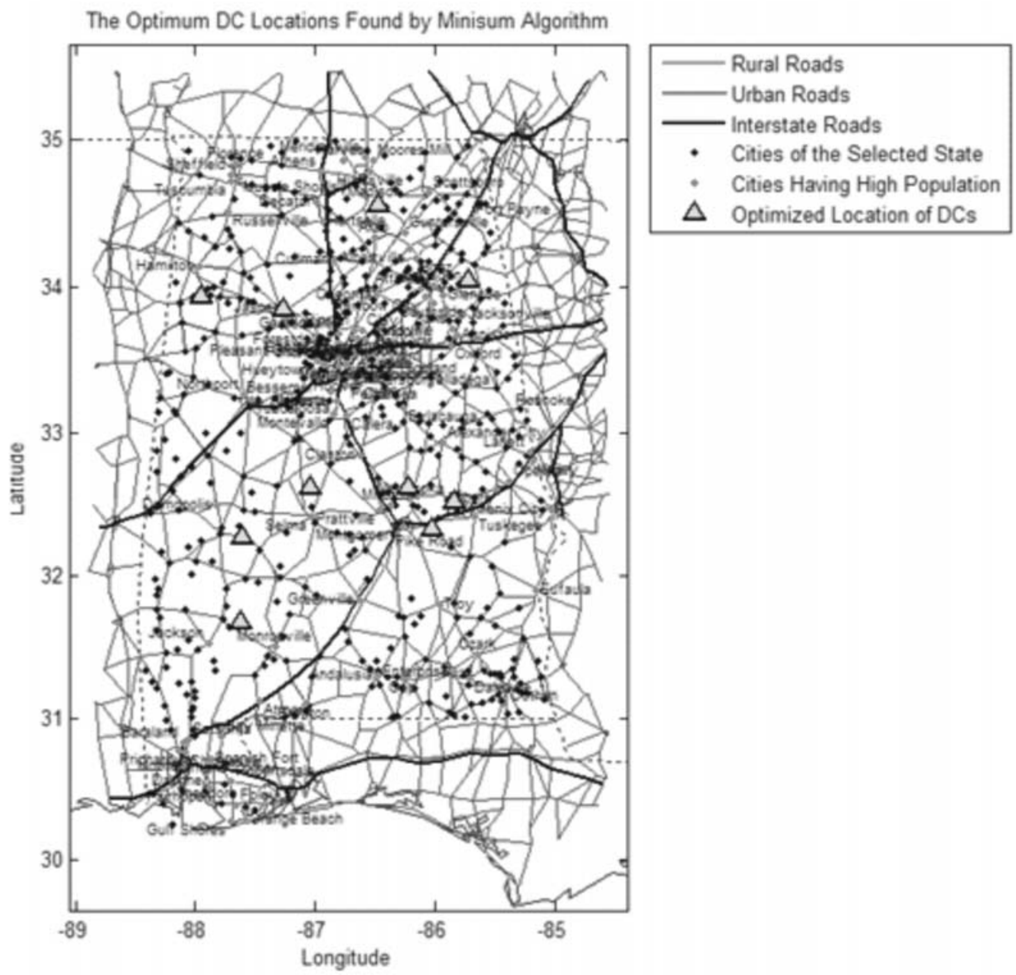

Fig. 7. The Average Distance between DCs and Customer Locations: 5.83 Units

The Time Taken for Finding Optimum Locations of DCs : 0.85 sec

3. AND DISCUSSION

We have implemented the proposed models for facility location in logistics analysis using Matlab software version R2012s. In this research, ALA and minisum functions were used from Logistics Engineering Toolbox (Matlog Version 16). We tried to use almost same input parameters for each evaluated method. We used the USA census data and map data which is much suitable for this kind of research. We decided to use USA data because, it is the only data refereed in some of the previous works and there seems no such detailed data available for any other country for validating the methods of facility location and logistics analysis.

The following table shows the overall results of this work.

Table 1. The Overall Performance

Facility Location Method	*Avg. Distance*	*Time Consumed*
Random	9.44	-
ALA	4.68	2.86
Minisum	5.83	0.85

The following graph shows the performance of algorithms in terms of the minimum average distance achieved. The average distance is the average of distance between all DCs and the Customer locations. Each Customer is bound with a nearest DC and the distance between each customer to that corresponding DC is calculated and then the average of all such distances were calculated. In this graph, the first column shows the reference distance which is nothing but the initial average distance of DCs that are randomly placed on the map.

With respect to the average distance, the proposed model performed well. It found the optimum facility locations better than the random/manual placements.

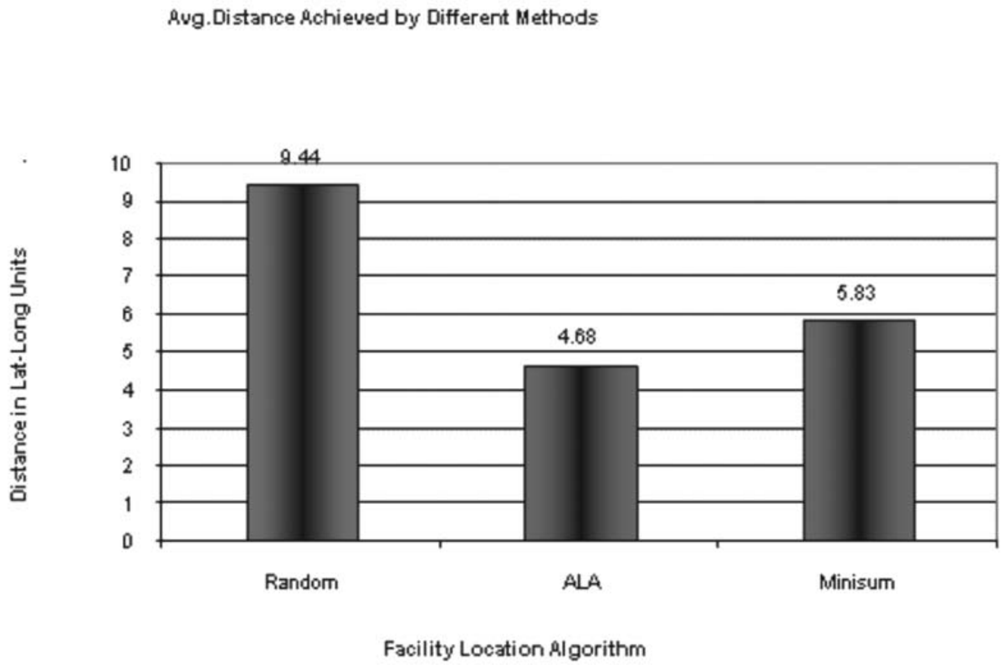

Fig. 8. The Performance in Terms of distance.

The following graph shows the performance in terms of cpu time. Even though the cpu time of minisum is low, it performed poor in terms of distance.

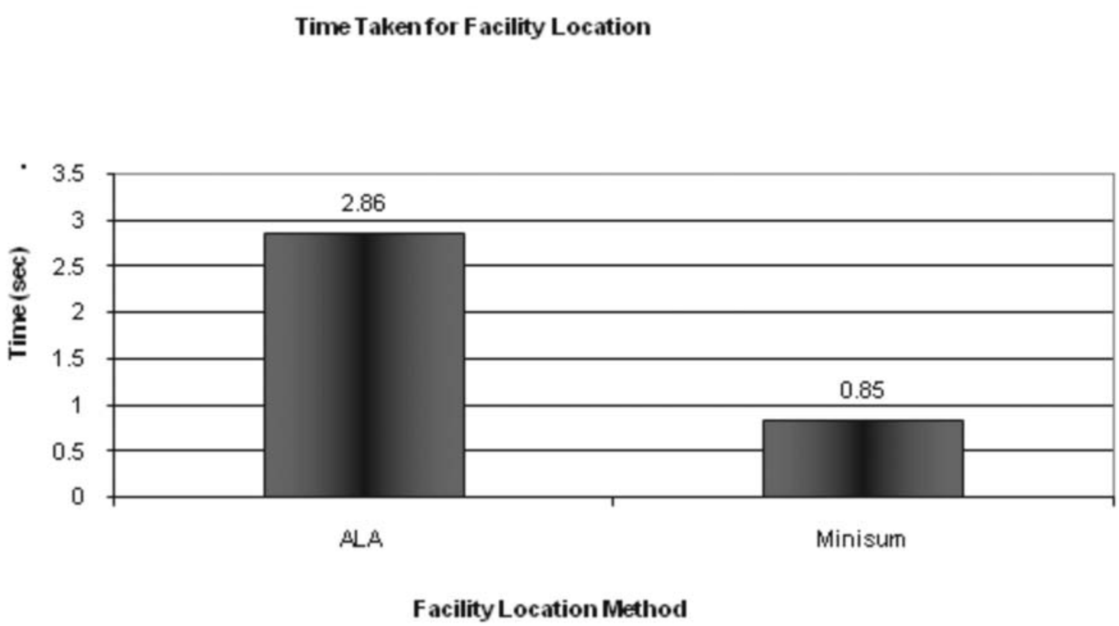

Fig. 9. The Performance in Terms of CPU Time.

4. CONCLUSION

Facility location for logistics is a wide area for research. In this work it addressed the possibilities of using ALA and minisum algorithm based models for facility location in logistic network design. As per the results, the proposed optimization models successfully found optimum locations of facilities in considerably meaningful time limit. In this work, a simple Euclidean distance function as a fitness function in the design of location optimization model. But, there are much more constraints and parameters in a practical logistics problem that can be included in the design of the fitness function such as (1) travel time with respect to road type, (2) loading unloading time at DCs, (3) different modes of travel times such as air travel time. This kind of more constraints and parameters can be included in future design of soft computing based optimization models. The future works will address these issues.

It has designed the proposed models as a single objective problem. But there are facility location and logistics situations where there may be more than one objective during optimization. Future works may address the design of soft computing based optimization models for multi objective optimization scenarios.

5. REFERENCES

http://mathforcollege.com/nm/nws/gen/090

1. Erlenkotter, D., "A Dual-Based Procedure for the Uncapacitated Facility Location." Operations Research, Vol 26(6), pg. 992-1009, 1978.
2. Francis, R.L., McGinnis, F.L., Jr., White, J.A., "Facility Layout and Location: An Analytical Approach." Prentice Hall, 2nd Ed., 1974.
3. Juliana Karakaneva, "A LOCATION PROBLEM MODELING AND SOLVING", Trakia Journal of Sciences, Vol 1, No 4, pp 1-7, 2003,ISSN 1312-1723, Copyright © 2003 Trakia University
4. HK Smith, G Laporte and PR Harper, "Locational analysis: highlights of growth to maturity", http://eprints.soton.ac.uk/68930/1/Locational_Analysis_-_Smith,_Laporte_and_Harper.doc
5. Michael J. Bucci, Michael G. Kay, Donald P. Warsing†, Jeffrey A. Joines, "Metaheuristics for Facility Location Problems with Economies of Scale", IIE Transactions
6. Michael J. Bucci, Ryan Woolard, Jeffrey Joines, Kristin Thoney, Russell E. King, "An Application of Heuristics Incorporating Economies of Scale to Facility Location Problems in Carpet Recycling"
7. .Biehl, M., Prater, E., Realff, M.J., 2007, Assessing performance and uncertainty in developing carpet reverse logistics systems, Computers and Operations Research, 34, 443-463.
8. .Brimberg, J.,Hansen, P., Mladenovic, N.,Taillard, E.D. ,2000, Improvements and Comparison of Heuristics for Solving the Uncapacitated Multisource Weber Problem, Operations Research, 48, 444-460.
9. Cooper, L., 1963, Location-allocation problems, Operations Research, 11, 331-343.
10. CARE (Carpet America Recovery Effort) annual report, 2007, http://www.carpetrecovery.org/pdf/annual_report/07_CARE-annual-rpt.pdf
11. CARE(Carpet America Recovery Effort)networkwebsite,2009, http://www.carpetrecovery.org/pdf/reclamation_centers/Carpet_Reclamation_Center s.pdf
12. Daskin, M.S., 1995, Network and discrete location: models, algorithms, and applications, John Wiley and Sons, New York.
13. De Brito, M.P., Dekker, R., Flapper, S.D.P., 2003, Reverse Logistics - a review of case studies, ERIM Report Series.

14. Fleishchmann, M., Krikke, H.R., Dekker, R., Flapper, S.D.P., 2000, A characterization of logistics networks for product recovery, Omega, 28, 653-666.

15. Louwers, D., Kip, B.J., Peters, E., Souren, F., Flapper, S.D.P., 1999, A facility location allocation model for reusing carpet, Computers and Industrial Engineering,

16. Mirchandani, P.B., Francis, R.L., 1990, Discrete Location Theory, Wiley, NewYork.

17. Realff, M.J., Ammons, J.C., Newton, D., 1999, Carpet Recycling: Determining the 38:3, 547-567.

18. Realff, M., Systems Planning for Carpet Recycling. 2006, Recycling in Textiles, Editor Youjiang Wang, CRC Press.

19. Shaju Varghese, Gladston Raj S, “A Genetic Algorithm Based Optimization Model for Facility Location in Logistic Network Design”, International Journal of Applied Engineering Research, Vol 10, No. 69, pp-338- 344, 2005, ISSN 0973-4562.

20. Shaju Varghese, Gladston Raj S, “Simulated Annealing and Direct Search Based Optimization Models for Facility Location in Logistic Network Design” International Journal of Computer Applications, Vol 132, pp- 31-37, December 2015, ISSN: 0975-8887.