Geographic Information System Based Solution for Location Allocation Problem for Finding High Quality Service Locations

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Abstract Location-Allocation Problem (LAP) is a combinatorial optimising network problem which has been widely studied by operational researchers due to its many practical applications. In real life, it is usually very hard to present the customer’s demands in a precise way and thus they are estimated from historical data. There are so many types of the methods like exact, heuristic and metaheuristic methods to solve this problem to get the optimal and near optimal solutions. In this study, a metaheuristic approach is applied in GIS environment which gives quick and near optimal solution. To achieve this, one case study based on supply and demand of milk from Vita Distributors to Vita Booths in Hisar City, Haryana have been performed. In this study, the effectiveness and robustness of the metaheuristic algorithm was tested over a GIS geodatabase based network dataset consisting of road network (line features) and facility and customers locations (point features). The performance of the algorithm was also checked for two types of impedance factors i.e. time and distance. The results of this location-allocation problem are very much satisfactory in term of minimization of total transportation cost in providing high quality service locations (Vita Booths) for milk distribution.

Keywords Metaheuristic algorithm; Network Analysis; Optimization; Transportation GIS

1. Introduction

Decision making is one of the main ability of human being that differ them from the other creatures. Now, decision making and analysis is an important part of management sciences, and it is perhaps as old as history of mankind. In many real-world problems, the decision maker likes to pursue more than one target or consider more than one factor or measure. Such a desire transforms the decision making problem to a multi-objective decision making problem. There are many decision making problems whose information is spatially (geographically) distributed. These kinds of decisions are called location decisions.

Location decisions are now a major part of operations research and management science (named location science). Facility location is a branch of operations research related to locating or positioning at least a new facility among several existing facilities in order to optimize (minimize or maximize) at least one objective function (like cost, profit, revenue, travel distance, service, waiting time, coverage and market shares). From application point of view there is no limitation for location science. Many application areas including public facilities, private facilities, military environment, business areas and national and international scopes can be seen in the related literature.
1.1. Background

In most scientific disciplines, software plays an important role for solving the real life problems and implementation of any concept. In field of transportation GIS, the examples of these real life problems are optimal path problem, location-allocation problem, minimum spanning tree problem, supply-demand problem, vehicle routing problem, travelling salesman problem, postman problem, maximum flow problem etc. In this study, the location-allocation problem is solved using GIS over a road transportation network in which GIS helps to find out the best suitable location for establishing a facility and identifying the total service area of the facility.

Transportation road network is defined as a system of interconnected point and line features through which resources flow. The network properties like connectivity, position & weights of network features, and direction of flow of resources over the network decided the type of the road network. The connectivity among the network elements is overall responsible to perform the network analysis based on the weight function (cost factor) of the features and direction of flow of resources from one element to another. The weight function represents basically the transportation cost from one location to another location over a network, and in GIS it is commonly known as the impedance factor. The transportation cost (impedance factor) can be calculated with respect to travel distance or travel time or any other factor which is directly or indirectly responsible for transportation cost between the geographical locations.

Location-Allocation Problem (LAP) is to locate a set of new facilities in an area of interest in order to satisfy the customer demands and minimizing total transportation cost from customer locations to facilities and vice versa. This problem arises in many practical urban settings where facilities provide homogeneous services such as the identification and location of ATMs, malls, warehouses, distribution centers etc. Many models have been presented for the solution of LAP, and numerous algorithms have been designed for these models, involving branch-and-bound algorithms, simulated annealing, Tabu search, heuristic and metaheuristic which is proved to obtain the best results when the number of facilities to locate is large.

1.2. Geographic Information System (GIS)

Geographic Information System (GIS) is a computer based system including hardware and software for collection, storage, manipulation, analysis and visualization of geographical data representing some geographic phenomenon on the Earth. The geographical data or geospatial data or geo-referenced data consists of spatial and non-spatial (attribute) information of the geographical features. GIS technology has a unique capability to integrate common database operations and spatial analyses with the visualization and geographic analysis benefits offered by maps. These abilities distinguish GIS from other information systems.

We commonly think of a GIS as a single, well-defined, integrated computer system. However, this is not always the case. A GIS can be made up of a variety of software and hardware tools which are useful to solve the real life problems. The basic idea behind the GIS Tool is to solve the specific problem using that tool for which it is developed. At the time of development of GIS tool for a specific problem, is to first understand that specific problem and then convert the problem into mathematical form (equation/inequalities) using certain method/algorithm. After that write the programme of these mathematical equations/inequalities using compatible programming language, and then develop the GIS tool for that specific problem. Finally, in reverse way this developed tool will help you to get the solution of that specific problem. GIS software is basically the integration of these tools to provide a smoothly operating, fully functional geographical data processing environment.
GIS has a unique capability in order to optimize the solution of network related problems in an efficient way. This study shows the optimization of Location-Allocation problem in an urban area which is based on the metaheuristic algorithm.

1.3. Topology

Topology is a famous term in mathematics which deals with the relationships among the features (elements). In GIS topology deals with the spatial relationship (connectivity, continuity and containment) of geographical features (point, line and polygon), and the relationships among the geometric features remains invariant under certain transformations. Topology is fundamentally used to ensure data quality and to aid in data compilation.

Geospatial topology studies the rules concerning the relationships between the points, lines, and polygons that represent the features of a geographic region. For example, where two polygons represent adjacent counties, typical topological rules would require that the counties share a common boundary without any gap or overlapping.

1.4. Location-Allocation Problem

Location-Allocation Problem (LAP) is consisting of two words location and allocation and are known as the elements of the problem. Locations are the places to put the central facilities, also called facility point, and allocation are the places where material demand is required and is also called customer location. LAP is basically locating the facilities and allocating the demands to the facilities. Its objective is to find locations for facilities and allocate customers (demands) to them in order to minimize the total transportation cost. In short, Location Allocation determines the optimal locations of a service in order to serve the population in the most efficient manner. Graphically it can be shown in Figure 1.

In this representation there are n facility points and n demand points which are geographically scattered. Where Xij is the quantity transported from ith facility location to jth customer location and Cij is the per unit transportation cost from ith facility location to jth customer location. Meta-heuristics techniques, which are more efficient search approaches for larger and more complicated problems than heuristics methods, are used in this study.
1.5. Location-Allocation Problem Types

Based on actual requirement of supply and demand of a material from facility points to demand points, the following types of Location-Allocation Problems (LAPs) are given below:

**Minimize Impedance:** In this type of the LAP, the facility points are located in such a way that the total weighted cost (demand allocated to the facility multiplied by the impedance to the facility) between customer location and facility location is minimized. This problem basically reduces the total transportation costs of delivery of items to the outlets or the total travel distance/time to reach the chosen facility point.

This problem type handles the demand based on the following criteria:

The demand locations are allocated to the facility according to the facility’s impedance (distance/time) cut-off value. Within the facility’s impedance cut-off value, demands are allocated to the facility, and outside the facility’s impedance cut-off value, demands are not allocated to that facility. A demand point inside the impedance cut-off value of two or more facilities has all its demand weight allocated to the nearest facility only.

**Minimize Facilities:** This problem describes that the facilities are located in such a way that as many demand points as possible are allocated to all facilities within the impedance cut-off. In addition to this, the total number of facilities required to cover all demand points is minimized. Minimize Facilities problem is the same as Maximize Coverage but with the difference of the less number of located facilities.

The points below describe demands handled by Minimize Facilities problem:

Any demand point outside the impedance cut-off of all the facilities is not allocated. A demand point inside the impedance cut-off of one facility has all its demand weight allocated to that facility. A demand point inside the impedance cut-off of two or more facilities has all its demand weight allocated to the nearest facility only.

1.6. Mathematical Formulation of Location-Allocation Problem

Let \( M = \{ M_i : 1 \leq i \leq m \} \) is a set of ‘m’ facility (supply) locations and \( N = \{ N_j : 1 \leq j \leq n \} \) is a set of ‘n’ demand (customer) locations. Consider \( a_i (1 \leq i \leq m) \) is the quantity available at supply (facility) location \( i \), and \( b_j (1 \leq j \leq n) \) is the quantity required at the demand (customer) location \( j \).

In order to model the location-allocation problem, the following indices, parameters, and decision variables are used:

\( (x_i, y_i) = \) coordinates of facility location \( i \), \( 1 \leq i \leq m \)

\( (l_j, k_j) = \) coordinates of customer locations \( j \), \( 1 \leq j \leq n \)
$C_{ij}$ = per unit transportation cost for delivering goods/material to customer $j$ from facility $i$, $1 \leq i \leq m$ & $1 \leq j \leq n$.

$D_{ij}$ = distance between the $i$th facility point and $j$th customer point, $1 \leq i \leq m$ & $1 \leq j \leq n$.

$X_{ij}$ = quantity transported from $i$th facility to $j$th customer.

$z_{ij} = \begin{cases} 
1 & \text{if customer } j \text{ is allocated to facility } i \\
0 & \text{otherwise} 
\end{cases} 

The decision variable representing number of customer locations assigned to $i$th facility is:

$$\eta_i = \sum_{j=1}^{n} b_j z_{ij} \text{ where } 1 \leq i \leq m$$

The objective function to minimize the total transportation cost can be written as:

$$Z = \text{minimize } \sum_{i=1}^{m} \sum_{j=1}^{n} X_{ij} C_{ij} D_{ij}$$

Subject to the following constraints:

1. $$\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j$$
2. $$\sum_{i=1}^{m} z_{ij} = 1 \quad \forall \ j$$
3. $$z_{ij} \in \{0,1\} \quad \forall \ i \ & \ j$$
4. $$X_{ij} \geq 0 \quad \forall \ i \ & \ j$$
5. $$C_{ij} \geq 0 \quad \forall \ i \ & \ j$$
6. $$\sum_{j=1}^{n} X_{ij} \leq a_i \quad \forall \ i$$
7. $$\sum_{i=1}^{m} X_{ij} \leq b_j \quad \forall \ i$$
\sum_{i=1}^{m} z_{ij} = b_j \quad \forall \ i \quad (8)

The constraint (1) assumes that the total supply is equal to the total demand, while constraints (2) assure that every customer is assigned with any of the facility. Constraint (3) is domain constraint while the constraints (4) and (5) are representing the quantity transported and transportation cost respectively. Constraints (6) is called supply constraint and (7) is called demand constraint.

2. Objectives and Questions

The main purpose of this study is to solve the location-allocation problem using metaheuristic algorithm over the Hisar city of Haryana state, and also to observe the performance of the algorithm. The sub-objectives of the study are:

- To create the digital database of Hisar City, Haryana in GIS environment for the solution of Location-Allocation problem.
- To create the topology and network dataset in order to optimize the results of Location-Allocation problem.
- To perform the network analysis and find out the solution of Location-Allocation problem under various real life situations like:
  - To determine the optimal vita distributors location for vita booths
  - To determine the optimal vita booths location for vita distributors
  - To minimize the vita distributors in order to fulfil the demands of vita booths
  - To maximize the total coverage of the vita distributors in order to serve the maximum vita booths.

![Figure 2: Study area (Hisar City, Haryana, India)](image-url)
Under this study the main research question over the optimality of results are: i) what are the essential attribute information of the network features required for the solution of LAP in GIS environment? ii) What are the essentially required attributes of the Network Dataset to optimize the result of LAP?

3. Study Area

In this study, Hisar City of Hisar district in Haryana state, India is identified as the study area. The study area is located between parallel 29°6'49″N to 29°11'57″N and meridian 75°40'53″E to 75°48'19″E in the western part of Haryana state, and at an average elevation of 215 m from mean sea level. It covers total area of 82.8648 km² and Figure 2 shows the geographical extent of the study area.

To perform the analysis we have digitized only vita distributors, vita booths and roads layers in our database of the study area.

4. Literature Review

Farahani et al. (2010) and Farahani et al. (2012) reviewed the recent efforts and development in multi-criteria location problems in three categories including bi-objective, multi-objective and multi-attribute problems and their solution methods. They have studied so few chapters or sections in different books but they have not seen any comprehensive review papers or book chapter that can cover it. Yanga et al. (2007) investigated location-allocation problem under fuzzy environment. Consequentially, chance constrained programming model for the problem to seek the approximate best solution of the model was designed and some properties of the model were investigated using Tabu search, genetic and fuzzy simulation algorithms.

Sha and Huang (2012) proposed an emergency blood supply scheduling model, in which they proposed a multi-period location - allocation model, and give the heuristic algorithm based on Lagrangian relaxation. Finally, they tested this algorithm over an example case study in the context of Beijing. A multi-criteria analysis based study on Nawabwip Municipality, West Bengal, India for Location-allocation of urban waste disposal sites, was done by Paul (2012).

Hongzhong et al. (2007) studied the general facility location problems and identify models used to address common emergency situations, such as house fires and regular health care needs and then then analyzed the characteristics of large-scale emergencies and propose a general facility location model that is suited for large-scale emergencies. Hussey et al. (1996) had studies the selection of landfill sites and associated problem particularly in the field of public health using geographic information system (GIS) based on parameters given by European Union Landfill directives. Curtin (2007) analyzed the network data structures and network location problems using GIS. Brimberg et al. (2000) and Brimberg et al. (2005) have compared the heuristics for solving multisource uncapacitated weber problem and also suggested the improvements for the solution. The study was extended by Brimberg et al. (2006) and Talbi (2009) for solving continuous field location-allocation problem for fixed cost of zones and implemented metaheuristics. They have also proposed the decomposition strategies for large-scale continuous location-allocation problems.

A constrained form of the classical Weber problem was investigated by Butt et al. (1996). In this problem, new facilities have been located in the presence of convex polygonal forbidden regions such that the sum of the weighted distances from the new facility to ‘n’ existing facilities is minimized. Silva et al. (2008) presented a comparative study of genetic algorithms (GA) and ant colony optimization
(ACO) applied the online re-optimization of a logistic scheduling problem based on the simulation. Silva et al. (2009) studies a Hub location problem which generally involve three simultaneous decisions to be made: the optimal number of hub nodes, their locations and the allocation of the non-hub nodes to the hubs.

AbdollahiDemneh et al. (2011) examined the emergency services facility location problem focusing on lose due to service delay. They have considered delay as a function of distance between the server and the customer. They formulated the problem as a mathematical model and then solve it efficiently for a numeral example. Hajipour et al. (2014) proposed a novel soft-computing approach based on the vibration theory called vibration damping optimization (VDO) to solve the Redundancy Queuing-Location-Allocation Problem. They developed a multiobjective version of the VDO called multiobjective VDO (MOVDO) based on the fast nondominated sorting and crowding distance concepts in the literature and the performance of the proposed MOVDO was statistically compared with the nondominated sorting genetic algorithm and multiobjective simulated annealing.

5. Materials and Methods Used

In this study, the used materials and adopted methodology are described below which perform vital role to achieve the assigned objectives.

Figure 3: Quick Bird image of study area
5.1. Material Used

**Satellite Data:** To create the digital database of the study area for the purpose of Location allocation problem, a high spatial resolution Quick Bird satellite data (Figure 3) is used in this study. Quick Bird satellite is a polar satellite and launched on October 2001 and has a revolution time of 93.4 minutes around the Earth. The images collected by this satellite have spatial resolution of 0.61 m (panchromatic) and 2.5 m (multispectral). The multispectral images consist of four bands in the blue (0.45–0.52 µm), green (0.52–0.60 µm), red (0.63–0.69 µm) and near-infrared (0.76–0.89 µm) wavelength regions, and panchromatic images has a spectral band of 0.45–0.90 µm. In this study, a merged product (0.61 m spatial resolution) of multispectral (2.5 m) and panchromatic (0.61 m) images dated June 3, 2011, was used for capturing geographical features (point & line) of the study area.

**Field Data:** To perform the location-allocation problem, we have also acquired attribute information of features (point & line) from the field. We have collected attribute information of Road features (road type, road name and allowed speed limit), Facility/Supply Point features (Facility name, coordinates, type of available material/goods) and Demand Points features (Name, coordinates, type of demanded material/good).

**Software Used:** In this study, we have used ESRI desktop product ArcMap 10 software for digital GIS database creation, spatial & non-spatial data entry & editing, topology creation, network data set creation and solving the location-allocation problem.

5.2. Method Used

In this study, the method used to perform the solution of LAP is shown in the flow chart shown in Figure 4.

First of all, we have prepared the digital GIS database in ArcGIS software which contains three types of the feature classes namely Roads (line), Vita Distributors which supply the milk, and Vita Booths which takes milk from Vita Distributors, and collected attribute information about these feature classes.
from the field. The coordinate system of database and satellite image was kept same i.e. WGS 84 datum, UTM projection and 43N zone. After that, we have entered the spatial data into all the feature classes by means of digitization over a satellite image. Once the data entry part is over, we have checked the digitization errors in the database and also corrected them by data editing tools.

Subsequently we have created topology of the database to remove remaining topological errors by creating various topological rules. And then a geo-database based network dataset was created using all the layers of database in GIS environment and decided different connectivity rules among different features, driving directions for easy access, turns and attributes of network dataset for optimal calculation.

For finding optimal allocation (demand) for each location (facility), we have decided the parameters of Location-Allocation layer and impedance factor. Finally, the analysis was performed and final results were generated.

In this study, we have considered two types of the bidirectional (From-to or FT and to-From or TF) impedance factors (cost functions) i.e. travel distance (meters) and travel time (minutes). For distance impedance, we have taken length of the road (shape_length) which is same along both the directions i.e. from-to (along the digitization direction) and to-from (opposite to the direction of digitization).

The time impedance factor was calculated using the road length (m) and speed limit of the road (km/h). It is not necessary that this impedance will be same along both the directions (FT and TF), so we have calculated it along both the directions separately using the following formula:

\[
FT\_Time\_minutes = \frac{0.06 \times SHAPE\_Length\ (m)}{FT\_Speed\ (km/hr)}
\]

\[
TF\_Time\_minutes = \frac{0.06 \times SHAPE\_Length\ (m)}{TF\_Speed\ (km/hr)}
\]

6. Results and Discussion

The results obtained are divided into different parts and discussed below:

6.1. Digital Database for LAP

The GIS database of the Hisar City (study area) was created in ArcGIS software. The database contains various feature classes (line & point) like roads, vita distributors and vita booths as shown in the Figure 5. In this database there are total 7556 roads having total shape length of 657652.4 meters, 3 vita distributors and 25 vita booths. After completing the GIS database, the topology of entire database was created to remove the topological errors of the database.

6.2. Network Dataset

The network dataset is basically a plate form where all the feature classes connect with each other and is essential to perform the solution of location-allocation problem in ArcGIS software. The network dataset was created using all the feature classes of the database where we have assigned the connectivity policy among different features, driving directions over the roads, turns at roundabouts, and created impedance factors for optimal path calculation. The created network dataset is shown in Figure 6.
In this GIS Network dataset we have created two types of impedance factors i.e. travel time (minutes) and travel distance (meters) for the calculation of optimal path. At the end of the creation of network dataset, there is another point feature layer, known as junction layer. These junctions are created at the intersection locations of line (road) features and stored in a separate layer.
6.3. Solutions of LAP

For finding out the solution of location allocation problem, we have considered the Vita distributors as the facility locations and vita booths as the demand locations where the material is to be allocated. The solution of LAP is assessed based on the different parameters in order to optimize the transportation cost in terms of driving time and travel distance. These are:

6.3.1. Minimize Impedance

In this case, the main objective is to minimize the total delivery cost of milk from vita distributor locations to vita booth locations. This type of problem is often called the P-Median problem. Here the solution of location allocation problem is shown based on two types of the impedance factors i.e. driving time and travel distance which are direct indicator of transportation/delivery cost.

Time Impedance: In this case the travel time impedance is minimized from vita booths (demand point) to vita distributors (facilities). In order to allocate all the vita booths with vita distributors, 7.3 minutes of cut-off time impedance was decided.

The optimal allocation of all the vita booths with the nearest vita distributors is shown in Figure 7.

Table 1: Attribute information of facilities
The attributes information of facilities layer is shown in Table 1. Here the weights and capacity (in litres) of all vita distributors is decided according to their importance. We have considered that all the vita booths are having same importance so the demand weight is same for all the vita booths i.e. 1 in this case. The total travel time & weighted travel time of all the assigned customers (vita booths) to each facility is shown in Table 1. Out of 25 vita booths 8 are allocated to PLA Vita Plant, 10 are allocated to HAU, Vita Plant and 7 are allocated to Rajeev Nagar Vita Plant.

The allocation detail of all the vita booths with the vita distributors and total travel time and distance from every vita booth to the concerned vita distributor is shown in Table 2.

**Table 2: Attributes of allocated vita booths with the vita distributors**

| Name                                           | DemandID | FacilityID | Total_Travel Time | Total Driving Distance |
|------------------------------------------------|----------|------------|-------------------|------------------------|
| GJU, Shopping Complex Booth - Rajeev Nagar, Vita Plant | 5        | 1          | 5.816293          | 3635.202403            |
| Civil Hospital Booth - Rajeev Nagar, Vita Plant       | 6        | 1          | 6.259567          | 3691.88064             |
| New Police Line - Rajeev Nagar, Vita Plant            | 19       | 1          | 5.497048          | 3664.806116            |
| Auto Market - Rajeev Nagar, Vita Plant                | 20       | 1          | 5.896906          | 3450.556572            |
| Indira Colony - Rajeev Nagar, Vita Plant             | 23       | 1          | 2.728035          | 1499.747716            |
| Shv Nagar - Rajeev Nagar, Vita Plant                  | 24       | 1          | 1.288921          | 671.33881              |
| Multani Chowk - Rajeev Nagar, Vita Plant             | 25       | 1          | 4.096141          | 2351.788713            |
| Jawahar Nagar Booth - HAU, Vita Plant                 | 1        | 2          | 1.472966          | 720.470109             |
| HAU Gate No 4 Booth - HAU, Vita Plant                 | 2        | 2          | 2.231802          | 1327.080783            |
| Bostal Hall - HAU, Vita Plant                        | 3        | 2          | 4.617836          | 3126.468009            |
| Azad Nagar Booth - HAU, Vita Plant                   | 4        | 2          | 5.04351           | 3434.777756            |
| Municipal Corp. Gate - HAU, Vita Plant                | 11       | 2          | 2.02229           | 1010.81897             |
| Court Complex - HAU, Vita Plant                      | 12       | 2          | 4.185531          | 2096.630267            |
| Old Court Complex - HAU, Vita Plant                  | 17       | 2          | 1.649777          | 847.301843             |
| Sector 14 - HAU, Vita Plant                          | 18       | 2          | 7.081286          | 4340.194446            |
| Madhuban Park - HAU, Vita Plant                      | 21       | 2          | 8.05354           | 425.395144             |
| Near Panchayat Bhawan - HAU, Vita Plant              | 22       | 2          | 0.042971          | 211.38628             |
| Vidyut Nagar 1 - PLA, Vita Plant                     | 3        | 3          | 6.699853          | 4105.622279            |
| Vidyut Nagar 2 - PLA, Vita Plant                     | 8        | 3          | 6.949732          | 4228.17161             |
| MC Colony - PLA, Vita Plant                          | 9        | 3          | 4.561222          | 2579.305366            |
| Vidyut Nagar 3 - PLA, Vita Plant                     | 10       | 3          | 7.291001          | 4569.33935             |
| Sector 16-17 - PLA, Vita Plant                       | 13       | 3          | 3.064557          | 1538.103187            |
| Sector 13 P-II - PLA, Vita Plant                     | 14       | 3          | 4.214814          | 2445.850537            |
| ITI Chowk - PLA, Vita Plant                          | 15       | 3          | 5.426948          | 3320.06153             |
| Jindai Hospital - PLA, Vita Plant                    | 16       | 3          | 9.1226            | 3379.070952            |

**Table 3: Attribute information of facilities**

| Name               | Weight | Capacity | Demand Count | Total_Driving_Distance | Total_Driving_Distance |
|--------------------|--------|----------|--------------|------------------------|------------------------|
| PLA, Vita Plant     | 1      | 3000     | 8            | 25669.770316           | 25669.770316           |
| HAU, Vita Plant     | 2      | 3800     | 10           | 17311.505846           | 17311.505846           |
| Rajeev Nagar, Vita Plant | 3  | 5000     | 7            | 18755.850515           | 18755.850515           |
Table 4: Allocation of vita booths with vita distributors

| Name                                      | DemandID | FacilityID | Total_Driving_Distance | Total_Travel_Time |
|-------------------------------------------|----------|------------|------------------------|-------------------|
| GJU, Shopping Complex Booth - Rajeev Nagar, Vita Plant | 5        | 1          | 3580.877611            | 6.358947         |
| CMII Hospital Booth - Rajeev Nagar, Vita Plant       | 6        | 1          | 3691.88064             | 6.259657         |
| New Police Line - Rajeev Nagar, Vita Plant           | 19       | 1          | 3575.708008            | 5.758961         |
| Auto Market - Rajeev Nagar, Vita Plant             | 20       | 1          | 3393.824988            | 6.109048         |
| Indira Colony - Rajeev Nagar, Vita Plant           | 23       | 1          | 1490.43175             | 2.729333         |
| Shiv Nagar - Rajeev Nagar, Vita Plant              | 24       | 1          | 671.33881              | 1.288921         |
| Multani Chowk - Rajeev Nagar, Vita Plant           | 25       | 1          | 2381.788713            | 4.081644         |
| Jawahar Nagar Booth - HAU, Vita Plant             | 1        | 2          | 720.470109             | 1.427966         |
| HAU Gate No 4 Booth - HAU, Vita Plant             | 2        | 2          | 1327.080783            | 2.231802         |
| Bostal Jall, Vita Booth - HAU, Vita Plant         | 3        | 2          | 3126.486009            | 4.617836         |
| Azad Nagar Booth - HAU, Vita Plant              | 4        | 2          | 3434.77756             | 5.0434           |
| Municipal Corp. Gate - HAU, Vita Plant           | 11       | 2          | 1010.811897            | 2.02229          |
| Court Complex - HAU, Vita Plant                  | 12       | 2          | 2098.630267            | 4.155531         |
| Old Court Complex - HAU, Vita Plant             | 17       | 2          | 847.301843             | 1.649277         |
| Sector 14 - HAU, Vita Plant                      | 18       | 2          | 4289.406245            | 7.236338         |
| Madhuban Park - HAU, Vita Plant                  | 21       | 2          | 426.398144             | 0.85349          |
| Near Panchoyat Bhawan - HAU, Vita Plant          | 22       | 2          | 21.138628              | 0.042971         |
| Vidyut Nagar 1 - PLA, Vita Plant                 | 7        | 3          | 4105.62227             | 6.698963         |
| Vidyut Nagar 2 - PLA, Vita Plant                 | 8        | 3          | 4228.81716             | 6.947932         |
| MC Colony - PLA, Vita Plant                      | 9        | 3          | 2579.30336             | 4.561222         |
| Vidyut Nagar 3 - PLA, Vita Plant                 | 10       | 3          | 4569.339835            | 7.291001         |
| Sector 16-17 - PLA, Vita Plant                   | 13       | 3          | 1538.101387            | 3.064557         |
| Sector 13 P-II - PLA, Vita Plant                 | 14       | 3          | 2445.850537            | 4.214814         |
| IIT Chowk - PLA, Vita Plant                      | 15       | 3          | 2962.202012            | 5.905003         |
| Jindal Hospital - PLA, Vita Plant                | 16       | 3          | 3240.532268            | 6.458868         |

**Distance Impedance:** The optimal allocation of vita booths based on distance (in meters) as a impedance factor with a cut-off value 4800 meters was studied. The allocation of all vita booths with concerned vita distributor is shown in Figure 8.

The attributes (like total sum of driving distances from each vita booths to the assigned facility, facility weights, no. of vita booths assigned to a vita distributor) of vita distributors layer are shown in Table 3.
The driving distances and travel time from each vita booths to solution facility is shown in Table 4. The allocation of all vita booths is also mentioned in ‘name’ field.

Figure 8: Minimize distance impedance

Figure 9: Solution of minimize facilities problem
6.3.2. Minimize Facilities

There are total 3 vita distributors which are serving all the 25 vita booths. To assign the optimal use of facilities, this number of facilities can be minimized and the total manufacturing cost can also be reduced for the business purpose. The problem was solved with 8 minutes of cut-off value of time impedance and it is found that only facilities are sufficient to serve all the demand points (vita booths) as shown in Figure 9. The serving facilities are shown by vita distributors feature and the facility which can be removing from the solution is shown by candidate feature in the Figure 9.

**Table 5: Attribute of facilities**

| Name                          | Facility Type | Weight | Demand Count | Demand Weight | Total Travel Time |
|-------------------------------|---------------|--------|--------------|---------------|-------------------|
| PLA, Vita Plant               | Candidate     | 1      | 0            | 0             | 0                 |
| HAU, Vita Plant               | Chosen        | 2      | 18           | 15            | 80.253799         |
| Rajeev Nagar, Vita Plant      | Chosen        | 3      | 7            | 7             | 31.571005         |

**Table 6: Allocation of vita booths to vita distributors**

| Name                          | Facility ID | Demand ID | Total Travel Time | Total Driving Distance |
|-------------------------------|-------------|-----------|-------------------|------------------------|
| Auto Market - Rajeev Nagar, Vita Plant | 1          | 20        | 5.896906          | 3450.55672             |
| Acad Nagar Booth - HAU, Vita Plant | 2          | 4         | 5.0434            | 3343.77776             |
| Bostai Jall, Vita Booth - HAU, Vita Plant | 2          | 3         | 4.617836          | 3126.49609             |
| Civil Hospital Booth - Rajeev Nagar, Vita Plant | 1          | 6         | 6.259657          | 3691.88064             |
| Court Complex - HAU, Vita Plant | 2          | 12        | 4.185531          | 2096.63027             |
| GJU, Shopping Complex Booth - Rajeev Nagar, Vita Plant | 1          | 5         | 5.816293          | 3635.20243             |
| HAU Gate No 4 Booth - HAU, Vita Plant | 2          | 2         | 2.231002          | 1327.08073             |
| Indira Colony - Rajeev Nagar, Vita Plant | 1          | 23        | 2.726036          | 1499.74776             |
| ITI Chowk - HAU, Vita Plant    | 2          | 15        | 5.92121           | 3781.41736             |
| Jawahar Nagar Booth - HAU, Vita Plant | 2          | 14       | 1.427967          | 720.470109             |
| Jindal Hospital - HAU, Vita Plant | 2          | 16        | 6.404822          | 3840.42816             |
| Mohanpur Park - HAU, Vita Plant | 2          | 21        | 0.85349           | 426.39514              |
| MC Colony - HAU, Vita Plant   | 2          | 9         | 5.03784           | 3040.66248             |
| Multani Chowk - Rajeev Nagar, Vita Plant | 1          | 25        | 4.096144          | 2351.72871             |
| Municipal Corp. Gate - HAU, Vita Plant | 1          | 11        | 2.02229           | 1010.81597             |
| Near Panchayat Bhawan - HAU, Vita Plant | 2          | 11        | 0.24291           | 21.138623              |
| New Police Line - Rajeev Nagar, Vita Plant | 1          | 19        | 5.497048          | 3664.80616             |
| Old Court Complex - HAU, Vita Plant | 2          | 17        | 1.649277          | 847.30184              |
| Sector 13 P-II - HAU, Vita Plant | 2          | 10        | 4.707376          | 2907.20749             |
| Sector 14 - HAU, Vita Plant   | 2          | 8         | 7.051206          | 4340.19446             |
| Sector 16-17 - HAU, Vita Plant | 2          | 13        | 6.93338           | 3543.54561             |
| Shri Nagar - Rajeev Nagar, Vita Plant | 1          | 24        | 1.238921          | 671.33581              |
| Vidyut Nagar 1 - HAU, Vita Plant | 1          | 7         | 7.191515          | 4566.97941             |
| Vidyut Nagar 2 - HAU, Vita Plant | 2          | 8         | 7.442294          | 4692.17473             |
| Vidyut Nagar 3 - HAU, Vita Plant | 2          | 10        | 7.735563          | 5203.697047             |

The facility name and type, facility weights, no. of allocated vita booth with the concerned facility and total sum of travel times from each vita booth to assigned facility are shown in Table 5.

The driving distances and travel time from each vita booths to solution facility is shown in Table 6. The allocation of all vita booths is also mentioned in ‘name’ field.

7. Conclusions

The crux of this study is to solve the location-allocation problem using metaheuristic algorithm. In order to achieve the objective we have comprehensively studied the allocation of demand points with the
supply points, and the same was applied for allocation of the veta distributors to the veta booths for the easy access of milk in order to minimize the impedance factor with respect to travel distance or travel time.

In this study, the effectiveness and robustness of the metaheuristic algorithm was tested over a GIS geodatabase based network dataset consisting of road network (line features) and facility & customers locations (point features). The performance of the algorithm was also checked for two impedance factors i.e. time and distance. The results of this location-allocation problem are very much satisfactory in term of minimization of total transportation cost in providing high- quality service to the veta distributors.

**Recommendations**

In this study we have solved the single objective location allocation problem which can be solved for multi-objective function too in future.

**References**

Abdollahi Demneh, S.M., Ghandehari, M. and Ketabi, S. 2011. A Location-allocation model for loss minimization in large-scale emergency situation. *Interdisciplinary Journal of Contemporary Research in Business*, 3(8), pp.954-964.

Brimberg, J. and Salhi, S. 2005. A continuous location-allocation problem with zone-dependent fixed cost. *Annals of Operations Research*, 136, pp.99-115.

Brimberg, J., Hansen, P. and Mladenovic, N. 2006. Decomposition strategies for large-scale continuous location-allocation problems. *IMA Journal of Management Mathematics*, 17, pp.307-316.

Brimberg, J., Hansen, P., Mladenovic, N. and Taillard, E.D. 2000. Improvements and comparison of heuristics for solving the uncapacitated multisource Weber problem. *Operations Research*, 48, pp.444-460.

Butt, S.E. and Cavalier, T.M. 1996. An efficient algorithm for facility location in the presence of forbidden regions. *European Journal of Operational Research*, 90, pp.56-70.

Curtin, K.M. 2007. Network analysis in geographic information science: review, assessment, and projections. *Cartography and Geographic Information Science*, 34(2), pp.103-111.

Farahani, R.Z., Asgari, N., Heidari, N., Hosseininia, M. and Goh, M. 2012. Covering problems in facility location: a review. *Computers and Industrial Engineering*, 62, pp.368-407.

Farahani, R.Z., Seifi, M.S. and Asgari, N. 2010. Multiple criteria facility location problems: a survey. *Applied Mathematical Modelling*, 34, pp.1689-1709.

Hajipour, V., Khodakarami, V. and Tavana, M. 2014. The redundancy queuing-location-allocation problem: a novel approach. *IEEE Transactions on Engineering Management*, 61(3), pp.534-544.

Hongzhong, J., Fernando, O. and Dessouky, M. 2007. A modeling framework for facility location of medical services for large-scale emergencies. *IIE Transactions*, (39), pp.1-41.
Hussey, V. Dodd, V. and Dennison, G.J. 1996. Locating a landfill site for Dublin using geographic information systems. *Proceedings of International Civil Engineering, Munic*, 115(3), pp.125-133.

Paul, S. 2012. Location allocation for urban waste disposal site using multi-criteria analysis: a study on Nabadwip Municipality, West Bengal. *International Journal of Geomatics and Geosciences*, 3, pp.74-88.

Sha, Y. and Huang, J. 2012. The multi-period location-allocation problem of engineering emergency blood supply systems. *Systems Engineering Procedia*, 5, pp.21-28.

Silva, C.A., Sousa, J.M.C. and Runkler, T.A. 2008. Rescheduling and optimization of logistic processes using GA and ACO. *Engineering Applications of Artificial Intelligence*, 21(3), pp.343-352.

Silva, M.R. and Cunha, C.B 2009. New simple and efficient heuristics for the uncapacitated single allocation hub location problem. *Computers and Operations Research*, 36(12), pp.3152-3165.

Talbi, E.G. 2009. Metaheuristics: from design to implementation. Wiley, p.624.

Yanga, L., Jib, X., Gaoa, Z. and Lia, K. 2007. Logistics distribution centers location problem and algorithm under fuzzy environment. *Journal of Computational and Applied Mathematics*, 208, pp.303-315.