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Location Of An Air Ambulance Response Unit In The Brong Ahafo Region Of Ghana Using The Planar K-Centra Single-Facility Euclidean Location Algorithm

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Abstract:
The Planar k-Centra Single-Facility Euclidean Location Algorithm was used to strategically locate an Air Ambulance Response Facility in the Brong Ahafo Region of Ghana which will be closest to the k-6 farthest districts. Sixteen (16) rectangular co-ordinates were generated for 16 district capitals as the inputs for the algorithm. Matlab codes were written and used to run the algorithm. The algorithm generated (397.3km, 929.2km) as the plane Cartesian rectangular coordinate of the optimal point with 273.8km as its objective function value which is given by sum of the distances of 6 farthest locations away from the optimal location. The proposed community for the Air Ambulance Response Facility was found to coincide with Tadieso, a village which is about nine (9) kilometres away from Techiman in the Brong Ahafo Region of Ghana.

Key words: *Ambulance; Planar K-Central; Euclidean; Optimization; Algorithm; Iteration.*

1.Introduction

An ambulance is a vehicle for transportation of sick or injured people to, from or between places of treatment for an illness or injury and in some instances will also provide out of hospital medical care to the patient. The word is often associated with road going emergency ambulances which perform part of an emergency medical service, administering emergency care to those with acute medical problems (Wikipedia, 17/09/2011).

The term ambulance does however extend to a wide range of vehicles other than those with flashing warning lights and sirens, including a large number of non-urgent ambulances which are for transport of patients without an urgent acute condition and a wide range of vehicles including trucks, vans, bicycles, motorbikes, station wagons, buses, helicopters, fixed-wing aircraft, boats and even hospital ships.

The term ambulance comes from the Latin word ‘ambmulare’, meaning to walk or move about which is a reference to early medical care where patients were moved by lifting or wheeling. The word originally meant a moving hospital, which follows an army in its movements. During the American Civil War vehicles for conveying the wounded off the field of battle were called ambulance wagons. Field hospitals were still called ambulances during the Franco-Prussian War of 1870 and in the Serbo-Turkish war of 1876 even though the wagons were first referred to as ambulances about 1854 during the Crimean War. (Wikipedia, 17/09/2011).

There are other types of ambulance, with the most common being the patient transport ambulance. These vehicles are not usually (although there are exceptions) equipped with life-support equipment, and are usually crewed by staff with fewer qualifications than the crew of emergency ambulances. Their purpose is simply to transport patients to, from or between places of treatment. In most countries, these are not equipped with flashing lights or sirens. In some jurisdictions there is a modified form of the ambulance used, that only carries one member of ambulance crew to the scene to provide care, but is not used to transport the patient. Such vehicles are called fly-cars. In these cases a patient who requires transportation to hospital will require a patient-carrying ambulance to attend in addition to the fast responder.

Air ambulances were useful in remote areas, but their usefulness in the developed world was still uncertain. Following the end of the World War II, the first civilian air ambulance in North America was established by the Saskatchewan government in Regina, Saskatchewan, Canada, which had both remote communities and great distances to consider in the provision of health care to its citizens. The Saskatchewan Air Ambulance Service continues to be active as of 2011 (Wikipedia, 17/09/2011)

A facility location problem can be classified according to the number of facilities involved. As shown in Figure 1, a new facility problem could be single or a multiple facility problem.

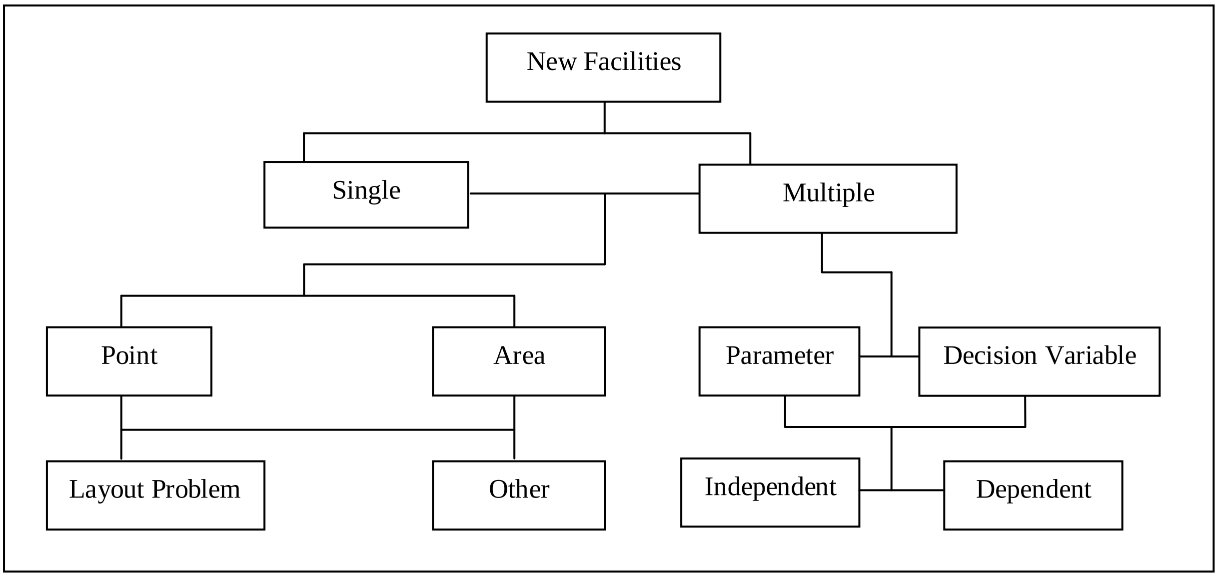

Figure 1: Type Of Location Problem

A single facility location can be locating a single point or an enclosed area. Multiple facility location problems can be problems defined by certain parameters like length or certain decision variables. The obtained solution can be dependant or independent of other parameters or decision variables. For examples, the new located point could be dependent or independent of the existing customer's location.

2.Planar K-Centra Single-Facility Location Problem

The objective of this work is to solve the planar k-centra single facility problem with Euclidean distances. The problem statement is to locate a single service point that minimises the sum of the distances to the k-farthest demand points out of a set of given points. A *k*-centra problem is a location analysis which encloses attributes from both the center as well as the median approaches. The solution procedure used in this work is an extension of one of the oldest heuristic methods existing in location science-Weiszfeld's algorithm. Starting out with $2n$ minimax solution (n being the number of demand points), the distance from the radius of the solution would be reduced until k points lie outside the circle. Then, minisum is applied on the problem and it is solved for the k points by considering the smallest possible circle that encompasses $(n – k)$ points. The solution is tested for feasibility, and if the original k points are outside the smallest circle, the solution is optimal. If not, this procedure is repeated again. The solution method used to solve this problem would be an Alternating Weiszfield's Algorithm. Here, Weiszfeld's algorithm would be alternated with reducing radius points until all k points are inside the smallest possible circle (one at a time) and then Weiszfled's is applied one more time. This method is repeated until optimality is obtained.

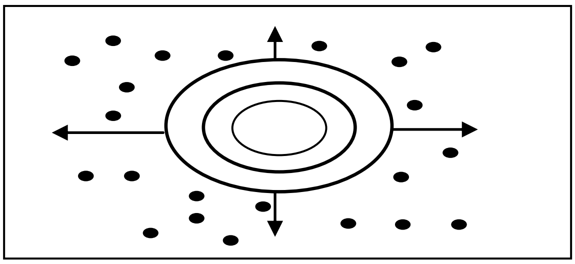

Figure 2: A Schematic Example Of The Single Facility K-Centra Problem

2.1.Problem Statement

The ambulance existed in most of the developed countries to transport sick or injured people to places of treatment. This function of the ambulance has saved a lot of life especially accident victims and has also reduce maternal mortality in most of the countries in the world. Ghana being a developing country, most of the health facilities lack requisite medical equipments to treat some of the complicated cases. In view of this most of the complicated cases are referred to the so called well-equipped hospitals for treatment. According to the Berekum Holy Family Hospital in the Brong Ahafo Region, in 2011, 7% out of 40 referred cases to the Sunyani Regional Hospital die before reaching the hospital. Base on this there is the need for a study that will come out with useful suggestions in order to minimize the situation. This prompted the researcher to locate a single service point (an air ambulance response unit) in the Brong Ahafo Region using the Planar K-Centra Single-facility Euclidean Location Algorithm to minimizes the sum of the distances to the k-farthest demand points out of a set of given points.

Due to poor road network in the region and sometimes traffic and speed rumps on the roads, some referred patients from clinics, maternity homes and hospitals die when being referred to regional hospital in Sunyani. The aim of this work is to use the Planner K-Centra Single-Facility Euclidean Location Problem Strategy to locate Air Ambulance Response Unit in the Brong Ahafo Region to minimize travel distances of K-6 farthest locations.

3.The Objectives Of The Study

The main objective of this paper is to contribute to the body of knowledge in the area of the optimal location of an air ambulance response unit by the Planar K-Centra Single Facility Euclidean Algorithm in the Brong Ahafo Region of Ghana.

3.1.Specific Objectives

Specifically, the paper seek among other things to;

minimize the travel distances of transferring patients from the primary hospitals to the Sunyani Regional Hospital in the Brong Ahafo Region.

reduce the rate at which patients die when they have been referred to Sunyani Regional hospital.

locate a centre that is not too far from all the centres and also quickly accessible to contribute to curb the situation.

4.Significance Of The Study

The study is significant because of the following reasons:

It will reduce the average travel time and distances from all the k-6 farthest costumer locations to the air ambulance response unit.

It will help to conserve fuel since the algorithm provides average shortest distances for all customer locations.

5.Literature Review

Hakimis (1964) introduced a seminal paper on locating one or more points on a network with the objective to minimize the maximum distance. Francis et al. (1983) presented a survey paper in location analysis which defined four classes of location problems and described algorithms to optimize them. They are continuous planar, discrete planar, mixed planar and discrete network problems. Daskin et al. (1998) reviewed various strategic location problems where they emphasized that a good facility location decision is a critical element in the success of any supply chain. They explained median problems, centre problems, covering problems, and other dynamic location problem formulations in the context of a supply chain environment. Location analysis goes back to the influential book of (the German industrial author Alfred Weber (1909). The research was motivated by observing a warehouse operation and its inefficiencies. Weber considered the single warehouse location problem and evaluated it such that the travel distances for pickups and replenishment were reduced. Other notable work in this field was by Fermat (1643), who solved the location problem for three points constituting a triangle. Another major concept in the field of location analysis was the concept of competitive location analysis introduced by (Hotelling, 1929). The paper discussed a method to locate a new facility considering already existing competition. The considered facilities were on a straight line. He proposed that the customers generally prefer visiting the closest service facility. He introduced the "Hotelling's Proximity Rule" which can be used to determine the market share captured by each facility. He just considered the distance metric during his analysis. The Hotelling model was extended by Drezner (1993) who introduced the concept of varying attractiveness among competing facilities. He analyzed cost and quality factors in addition to distance metric involved. Huff (1966) proposed the famous "Gravity Model" for estimating the market share captured by competitors. The gravity model states that existing customer locations attract business from a service in direct proportion to the existing locations and in inverse proportion to the distance between the service location and the existing customer locations.

5.1.Rectilinear Distance Metric Problem

The rectilinear distance location problem is a variant of the classic location problem. Rectilinear distance metric is the axial distance between two corresponding points taken at right angles from each other. Francis (1963) first considered the single facility location problem with rectilinear distances. The paper considered a simple substitution method for solving the proposed problem. Francis (1964) also solved the multi-facility rectilinear location problem with equal demand weights. The objective function is as given by Equation 2.1.

Minimize f (x) = ∑ (i = 1…m)Wi.d (X, Pi) …………………….(2.1)

Where;

Wi = Weights associated with the locations.

m = Number of existing locations

5.2.Euclidean Distance Metric Problem

The difference between Euclidean and rectilinear distances is that where rectilinear distance metric considers right-angle distances, a Euclidean metric considers straight line distances between points. In a plane with a points at (x_1, y_1) and (x_2, y_2), it is given by Equation 2.2.

Minimize $f(x, y) = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$ ……………..(2.2)

This problem is also known as the Weber problem. It is also known as the planar Euclidean minisum distance single facility location problem, which adequately defines its characteristic. The upper and lower bound on f_{euc} is as shown in Equation 2.3.

$\sqrt{f_1(x)^2 + f_2(y)^2} <= f_{euc}(x^*_{euc}, y^*_{euc}) <= f_{euc}(x^*_{rec}, y^*_{rec})$ ……..……..(2.3)

For collinear single facility location problems with Euclidean distances, a user can alays obtain an optimal solution as discussed in the paper by (Rosen et al., 1993). This work assumes that the existing facilities are non-collinear. For non collinear location problems, Weiszfield (1937) was the first to propose a fixed-point iterative method that is known as the Weiszfield procedure. Weiszfield's alogarithm iteratively solves for the minisum location to the Weber problem based on the objective function.

Drezner (1985) in his paper conducted some sensitivity analyses for the single facility problem. He studied various variants of the problem with weight restrictions and location restrictions.

5.3.Location-Allocation Problems

Since 1963, when the first location-allocation model was formulated by Cooper (1963), there has been extensive research on the field. The simplest location-allocation problem is the Weber problem addressed by (Friedrich, 1929). This paper discussed the steps in locating a machine so as to minimize the sum of the weighted distances from all the raw materials sources. The seminal work in this area was on the p-median problem, initially formulated by (Hakimi, 1964). The median problem was considered on a graph and the objective function was to reduce the average or the sum of the transportation costs from the service facility to the demand locations. It was derived that one of the optimal solutions locates the service facility on one of the nodes of the network. Halpern (1976) first introduced the cent – dian model as a parametric solution concept based on the bicriteria center/median model. Halpern modelled the problem in such a way that a compromise was achieved between median and centre objective functions such that the inherent objective function characteristics of both the problems are considered while solving. The two objective functions considered are total distance minimization and the maximum distance minimization criterions. The goal here was to find an optimal balance between efficiency (least - cost) and equity (worst - case). However, this particular method can sometimes fail to provide a solution to a discrete location problem mostly due to the limitations involved with direct combinations of two different functions. Hansen et al. (1991) introduced a variation of the cent – dian problem in the generalized center problem, which minimizes the difference between the maximum distance and the average distance. This model can be extended to formulate solutions for multiple facility location problems on a plane as well as on a network. This model can also be applied to discrete location problems. The k – centra problem concept was formulated by (Slater, 1978). The k – centra model combines both the center as well as the median concepts by minimization of the sum of the k largest distances. If k = 2 the model reduces to a standard center problem while with k=n it becomes a standard median problem. This paper concentrated on the discrete single facility location problem on a tree graph. Peeters (1998) studied the k – centrum model and introduced a full classification of the k – centrum criteria and some solution concepts. He proposed two different variations on the median and the center functions each. The functions considered were upper k – median where the sum of the k largest distances are minimized, lower k – median where the sum of the k smallest distances are minimized, upper k – center where the k largest distances are minimized, and lower k– center where the k smallest distance are minimized. The k–centrum model is generally reserved for unweighted problems. However, significant research has been performed to show that satisfying the above criteria is not always necessary. Recently, Tamir (2001) solved a weighted multiple facility k – centrum problem on paths and tree graphs using simple polynomial time algorithms. In this method, weights are assigned to all the distances from the new location to the existing locations and the distances are scaled accordingly. Ogryczak and Zawadski (2002) in their paper introduced the conditional median method which is an extension of the k-centrum concept when applied to weighted problems. The paper proposes that a k-centrum problem can be evaluated for optimality by just considering only that specific part of the demand which is in direct proportion to the existing largest distances for a specified portion of the demand.

6.Research Methodology

The formulation of an optimization problem involves the development of a mathematical model for the physical or engineering problem. In practice, several assumptions have to be made to develop a reasonably simple mathematical model that can predict the behavior of the system fairly accurately. The results of optimization will be different with different mathematical model of the same physical system. Hence, it is necessary to have a good mathematical model of the system, so that the results of optimization can be used to improve the performance of the system. A general optimization problem can be stated in mathematical form as

$$\text{Find } \vec{X} = \begin{Bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{Bmatrix}$$

that minimizes $f(\vec{X})$

subject to:

$g_j(\vec{X}) \leq 0; \quad j = 1, 2, \ldots, m;$

and

$h_k(\vec{X}) = 0; \quad k = 1, 2, \ldots, p;$

where x_i ($i = 1, 2, \ldots, n$) are the decision variables, $\vec{X}$ is the vector of decision variables, f ($\vec{X}$) is the merit, or criterion, or objective, function, $g_j(\vec{X})$ is the jth inequality constraint function that is required to be less than or equal to zero, $h_k(\vec{X})$ is the kth equality/ Constraint function that is required to be equal to zero, n is the number of decision variables, m is the number of inequality constraints, and p is the number of equality constraints.

6.1.Data Collection And Modeling

The Weizszfeld's algorithm is the objective function used to minimize the sum of the distances between the existing demand locations and the new facility location. Weiszfeld algorithm can be used to solve planar as well as network problems considering two-dimensional or three-dimensional coordinates. Weiszfeld's algorithm iteratively solves for the minisum location to the Weber problem based on its objective function as shown in equation 3.1.

Minimize $f(x, y) = \sum wi \sqrt{(x-a_1)^2 + (y-b_1)^2}$ 3.1

Where,
w_i = weight's associated with the existing locations
x = x coordinate of the starting solution and later obtained by successive iterations.
y = y coordinate of the starting solution and later obtained by successive iterations.
a_i = x coordinate of existing locations b_i = y coordinate of existing locations.
Equation 3.1 is the sum of the weighted distance.

6.2.The Weiszfeld's Algorithm

The steps followed in Weiszfeld's Algorithm to solve a planar Euclidean location problem are as listed below:
Step1: Input initial coordinates (x,y).
Step 2: Solve for every γ_i as per Equation 3.2.

$$\gamma_i = \frac{wi}{\sqrt{(x-a_i)^2 + (y-b_i)^2}} \quad \text{.......... (3.2)}$$

Where, x= x-coordinates of starting point for the iterative algorithm.

y = y-coordinates of starting point for the iterative algorithm.

Step 3: sum for every γ_i for Γ(x,y) shown by Equation 3.3.

$$\Gamma(x, y) = \sum_{i=1}^{m} \gamma_i (x, y) \quad \text{..........(3.3)}$$

Step 4: determine all $\lambda_i = \gamma_1/\Gamma$ as shown in Equation 3.4.

$$\lambda_i(x,y) = \frac{\gamma_i (x,y)}{\Gamma(x,y)} \quad \text{..........(3.4)}$$

Step 5: Weiszfeld's (x) = WFx = $\sum (i = 1 \ldots m) \lambda_i . a_i$ ……………(3.5)

Weiszfeld's (y) = WFy = $\sum (i = 1 \ldots m) \lambda_i . b_i$ …………….(3.6)

Step 6: Determine the objective function value by summing the individual objective function values for all i as per Equation 3.7.

$$f_{euc} = \sum w_i \sqrt{(WFx - a_i)^2 + (WFy - b_i)^2} \quad \text{..........(3.7)}$$

Step 7: Repeat until stopping conditions are met that is $|f_{eucn+1} - f_{eucn}| \leq 0$ 3.8
Considering a random starting solution, the algorithm is evaluated to obtain a second set of trial values (WFx, WFy). The obtained coordinates are substituted to obtain the third set of trial values and so on. By reiterating the Weisfeld's values for x, y, we can find the Euclidean solution close to or equal to the optimal solution. The stopping conditions are met when the difference between subsequent objective function values obtained is less than or equal to zero.

6.3.Data Collection

The Government Agency that was contacted for the primary data and other important information for this work was the Regional Town and Country Planning Department (Sunyani) where the map of the Brong Ahafo Region was obtained.The names of the hospitals in the region was also obtained from the regional headquarters of National Health Insurance Authority (NHIA) and the data on the number of referred cases was taken from the transport unit of Berekum Holy family Hospital and Sunyani Regional Hospital.

Data	Source
Map of Brong-Ahafo Region	Regional Town and Country Planning Department
Names of Hospitals in the Region	National Health Insurance Authority (NHIA)
Referred Cases	Berekum Holy Family Hospital and Sunyani Regional Hospital

Table 1: Table Showing Sources Of Data
Source: Research's Fieldwork (2012)

6.4.Data Processing

The rectangular co-ordinates of the district capitals were obtained with the help of a grid sheet since the co-ordinates could not be found on the internet (Google map and Microsoft Encarta).The district capitals were coded as numbers from 1 to 16. The co-ordinates were converted from hundred thousand to hundreds. For example, the co-ordinate for Asunafo North becomes (379, 899) instead of (379000, 899000).

NUMBER	DISTRICT CAPITAL	X(a_i) in km	Y(b_i) in km
1	ASUNAFO NORTH	379	899
2	ASUTIFI	386	908
3	BEREKUM	376	926
4	DORMAA AHENKRO	364	915
5	JAMAN NORTH	374	943
6	JAMAN SOUTH	366	929
7	KINTAMPO NORTH	416	962
8	KINTAMPO SOUTH	408	944
9	NKORANZA SOUTH	408	927
10	PRU	459	951
11	SENE	465	933
12	SUNYANI	385	919
13	TANO NORTH	399	914
14	TANO SOUTH	398	911
15	TECHIMAN	403	928
16	WENCHI	393	937

Table 2: Table Showing Number Codes For District Capitals And Their Various X And Y Co-Ordinates

6.5.The Planar K-Centra Algorithm

The sixteen rectangular co-ordinates were used as the inputs for the Planar k-Centra Single-Facility Euclidean Location Problem Algorithm coded in Mathlab. The steps for the algorithm are shown below;

Step1: Input initial coordinates (x, y), the minimax.

Step 2: Solve for every γ_i as per Equation 4.1.

$$\gamma_i = \frac{wi}{\sqrt{(x-a_i)^2 + (y-b_i)^2}} \qquad \text{…………………(4.1)}$$

Where,

x = x-coordinates of starting point for the iterative algorithm

y = y-coordinates of starting point for the iterative algorithm

Step 3: sum for every γ_i for Γ(x,y) shown by Equation 4.2.

$$\Gamma_1(x,y) = \sum_{i=1}^{m} \gamma_i\,(x,y) \qquad \text{…………..… (4.2)}$$

Step 4: determine all $\lambda_i = \gamma_i/\Gamma$ as shown in Equation 4.3

$$\lambda_i(x,y) = \frac{\gamma_i(x,y)}{\Gamma(x,y)} \quad \text{.............. (4.3)}$$

Step 5: Weiszfeld's (x) = WFx = $\sum (i = 1\ldots m)\ \lambda_i.a_i$ .... (4.4)

Weiszfeld's (y) = WFy = $\sum (i = 1\ldots m)\ \lambda_i.b_i$ .... (4.5)

Step 6: Determine the objective function value by summing the individual objective function values for all *i* as per Equation 4.6.

$$f_{euc} = \sum w_i \sqrt{(WFx - a_i)^2 + (WFy - b_i)^2} \quad \text{................ (4.6)}$$

Step 7:Repeat until stopping conditions are met that is $| f_{eucn+1} - f_{eucn} | \leq 0$

Considering a random starting solution, the algorithm is evaluated to obtain a second set of trial values (WFx, WFy). The obtained coordinates are substituted to obtain the third set of trial values and so on. By reiterating the Weisfeld's values for x, y, we can find the Euclidean solution close to or equal to the optimal solution. The stopping conditions are met when the difference between subsequent objective function values obtained is less than or equal to zero.

6.6.Computational Procedure

Matlab program software (Siddarth, 2005) was used for the coding of the Planar k-Centra Single-Facility Euclidean Location Problem algorithm. The codes were developed and ran on the Intel(R) Pentium(R) Dual CPU T2370, 32 BG Operating system, 1014 MB RAM, 1.73 GHZ speed, with Windows Vista laptop computer. The code runs successfully on the windows vista.The number of iterations was 100 and 4 test runs were carried out.

7.Results And Discussions

The results based on the Matlab solution through 100 Iterations with estimated model are provided in this section of the paper.

NO.	X km	Y km	f km		NO.	X km	Y km	f km
1	398.5	929.5	273.8		2	398.2	929.7	273.8
3	398.2	929.6	273.8		4	397.9	929.6	273.8
5	397.8	929.5	273.8		6	397.8	929.5	273.8
7	397.6	929.4	273.8		8	397.6	929.4	273.8
9	397.5	929.4	273.8		10	397.5	929.3	273.8
11	397.5	929.3	273.8		12	397.4	929.3	273.8
13	397.4	929.3	273.8		14	397.4	929.3	273.8
15	397.4	292.3	273.8		16	397.4	929.3	273.8
17	397.4	929.3	273.8		18	397.3	929.3	273.8
19	397.3	929.3	273.8		20	397.3	929.3	273.8
21	397.3	929.3	273.8		22	397.3	929.3	273.8
23	397.3	929.3	273.8		24	397.3	929.3	273.8
25	397.3	929.2	273.8		26	397.3	929.2	273.8
27	397.3	929.2	273.8		28	397.3	929.2	273.8
29	397.3	929.2	273.8		30	397.3	929.2	273.8
31	397.3	929.2	273.8		32	397.3	929.2	273.8
33	397.3	929.2	273.8		34	397.3	929.2	273.8
35	397.3	929.2	273.8		36	397.3	929.2	273.8
37	397.3	929.2	273.8		38	397.3	929.2	273.8
39	397.3	929.2	273.8		40	397.3	929.2	273.8
41	397.3	929.2	273.8		42	397.3	929.2	273.8
43	397.3	929.2	273.8		44	397.3	929.2	273.8
45	397.3	929.2	273.8		46	397.3	929.2	273.8
47	397.3	929.2	273.8		48	397.3	929.2	273.8
49	397.3	929.2	273.8		50	397.3	929.2	273.8
51	397.3	929.2	273.8		52	397.3	929.2	273.8
53	397.3	929.2	273.8		54	397.3	929.2	273.8
55	397.3	929.2	273.8		56	397.3	929.2	273.8
57	397.3	929.2	273.8		58	397.3	929.2	273.8
59	397.3	929.2	273.8		60	397.3	929.2	273.8
61	397.3	929.2	273.8		62	397.3	929.2	273.8

63	397.3	929.2	273.8		64	397.3	929.2	273.8
65	397.3	929.2	273.8		66	397.3	929.2	273.8
67	397.3	929.2	273.8		68	397.3	929.2	273.8
69	397.3	929.2	273.8		70	397.3	929.2	273.8
71	397.3	929.2	273.8		72	397.3	929.2	273.8
73	397.3	929.2	273.8		74	397.3	929.2	273.8
NO.	**X km**	**Y km**	**f km**		**NO.**	**X km**	**Y km**	**f km**
75	397.3	929.2	273.8		76	397.3	929.2	273.8
77	397.3	929.2	273.8		78	397.3	929.2	273.8
79	397.3	929.2	273.8		80	397.3	929.2	273.8
81	397.3	929.2	273.8		82	397.3	929.2	273.8
83	397.3	929.2	273.8		84	397.3	929.2	273.8
85	397.3	929.2	273.8		86	397.3	929.2	273.8
87	397.3	929.2	273.8		88	397.3	929.2	273.8
89	397.3	929.2	273.8		90	397.3	929.2	273.8
91	397.3	929.2	273.8		92	397.3	929.2	273.8
93	397.3	929.2	273.8		94	397.3	929.2	273.8
95	397.3	929.2	273.8		96	397.3	929.2	273.8
97	397.3	929.2	273.8		98	397.3	929.2	273.8
99	397.3	929.2	273.8		100	397.3	929.2	273.8

Table 3: Matlab Solution To Generate Points For Scatter Plot (100 Iterations)

The minimax location was (414.0km, 927.0km). The algorithm gave one location as the optimal point. That is (397.3km, 929.2km) and with 273.8km as the objective function value (The sum of the distances of 6 farthest locations away from the optimal location).

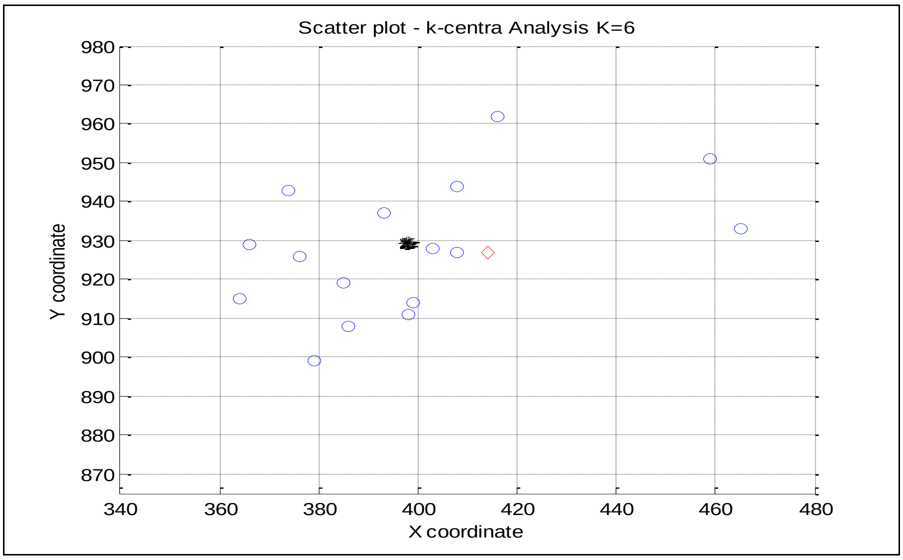

Figure 3: The Sixteen (16) Scatter Points, The Diamond Figured Point And The Asterisk Point.

7.1.Discussion Of Results

The algorithm gave one location as the optimal point. That is (397.3km, 929.2km) with273.8km as the respective objective function value (The sum of the distances of 6 farthest locations away from the optimal location). The Scatter plot above indicates the red diamond figured which is the minimax (414.0, 927.0), the asterisks point is the optimal point (397.3051, 929.2434). The blue dots are the 16 points for the District capitals of Brong Ahafo Region which were used for the work.

7.2.Conclusion And Recommendations

The Planar k-Centra Single-Facility Euclidean Location Problem Algorithm has been successfully applied using the rectangular co-ordinates of the district capitals of the Brong Ahafo Region to locate an air ambulance response unit. This work is similar to the facility located by Fernandez, et al. (2009) in the city of Murcia in South-East Spain. Matlab codes were written to determine the strategic location. The algorithm generated one location. That is (397.3km, 929.2km) with 273.8km as the objective value. Hence the proposed location for the Air Ambulance Response Unit in the Brong Ahafo Region is the point 397.3km, 929.2km. Practically, the proposed community is at Tadieso on the Techiman – Kumasi road. The road network at Tadieso is a first class road that links Techiman to other parts of the region.

7.3.Recommendations

Based on the study, the following recommendations are made:

The Air Ambulance response unit should be located at Tadieso on Techiman-Kumasi Road.
This work should serve as basis for further research in the area of Planar k-Centra Single-Facility Euclidean Location Problem.
Since Brong Ahafo Region was used as the case study, the researcher recommends the point (397.3km, 929.2km) which is located at Tadieso to the regional office, contractors, urban and feeder roads and other developers (Stakeholders) that Tadieso is one of the most closest to the six (6) farthest districts in the region.

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