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# Facility Location Problems in the Presence of Mixed Forbidden Regions

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**Abstract**

This paper presents the methodology to obtain the optimum facility location in the presence of polygonal and elliptical forbidden regions. The algorithms to compute the shortest unconstrained Euclidean distances are presented. In case of the elliptical and polygonal forbidden regions Further Reduced Search Area (FRSA) Technique is used. This approach overcomes the inadequacies of earlier techniques and can yield solutions to problems involving elliptical and polygonal forbidden regions. The MATLAB programming is graphic interactive and enables the user to continuously monitor the state and progress of computation. Min-sum criteria have been used to find optimum location of a new facility through revised Hook and Jeeves search method.

**Keywords:** Unconstrained path- Euclidean norm- facility-Hook and Jeeves method- FRSA-forbidden region.

## INTRODUCTION

Real life environments, at macro level, for example erection of power grid lines over wide areas consisting of hills and huge industrial complexes demand identification of electrical grid lines that can neither be neither located within a hilly / industrial area nor permitted to pass through them. Majority of the industrial complexes in general have their infrastructure built into either a rectangular, square or some times polygonal shaped land areas. Whereas natural regions like hills have their footprints that are most nearer to a circle or an ellipse and also a polygon. So identification of the shortest gridline connecting two planar points under the influence of barriers like hills, industrial complexes etc., constitutes an important and practical locational problem that has some economic relevance.

At micro level i.e., in industrial centers identification of routes that minimize handling / transportation costs throw-open many a challenge especially for the fact that industrial areas / yards normally consist of several other facilities of functional importance that permit neither location nor travel through them. For example, huge gib cranes operating in heavy industries normally have functional operational reach confined to a circle or an ellipse. These together with other facilities consisting of buildings constitute a situation wherein a combination of an elliptical and polygonal forbidden region is encountered. Circumstances leading to identification of a new facility that interacts with a set of existing facilities scattered around, in the presence of elliptical and polygonal barriers therefore constitutes a potential locational / layout problem. In view of the economic importance, especially under high frequency interactive situations, the author makes an attempt to develop a locational model that can give solutions to problems involving location of a new interacting facility among a set of existing facilities and under the influence of forbidden / barrier regions that can be approximated to an ellipse and a polygon.

In approximating a region to either a circle or an ellipse the criteria behind was roughly the shape of the prohibited area. Further, while developing various computational models the assumption of the geometric shape is limited to exclusive circles or ellipses. The extensive literature survey made reveals that no specific work has been reported on locational problems with two forbidden regions consisting of a polygon and an ellipse.

Katz and Cooper [1,2] have contributed work in the area of location planning with circle forbidden region(s). Single facility location planning in the presence of a circle forbidden region reported by them uses the calculus of variations to compute the shortest constrained distances between any two points in the plane for Euclidian norm. They applied Sequential Unconstrained Minimization Technique (SUMT), to determine the optimal (near optimal) location for the new facility relative to a number of existing facilities, which involved complicated and laborious mathematical computations of angles. An improvement upon Katz and Cooper [2] was reported by Ravindranath, K., et al. [4] who developed two procedures to compute the shortest Euclidian and rectilinear distances respectively between any two points in the plane in the presence of a single circle forbidden region. The method due to Ravindranath, K., et al. [4] involved the partitioning of the feasible region in to 12 distinct subsets. Then, systematic search was carried out to find to which of the subsets, the location of the new facility belonged to. And then computation of shortest constrained distance was made which again involved more computational effort. Seshasayee, K. R., et al. [5] in their work have reported two simple algorithms developed to compute the shortest constrained Euclidian/rectilinear distances between any two points in a plane in the presence of a single circle forbidden region. Raju, K.V.L., et al. [6], proposed an elegant algorithm which avoids computation of distances in all possible paths and automatically selects the shortest path based on the relative position of the line joining source, destination with respect to center of the two circles. The methodology proposed by Raju, K.V.L., et al. [7] is employed effectively to locate new facility in the presence of single and two circle forbidden region(s). But in the method the search is made over the entire feasible solution space and the weights for the existing facilities are considered as unity. Mohan, K. V. V., et al. [8] used the technique developed by Raju, K.V.L., et al. [7] for obtaining network of paths under static considerations in the presence of single and two forbidden regions. This amounted to computation of all alternate paths. Also, being a network related problem does not involve any locational aspect which normally requires dynamic computational environment. Dr. K.V.L.Raju.et al., [9] have used modified Sloping Line Search (SLS) Technique to compute the shortest Euclidean distance between any two facilities where the path is constrained by two polygonal forbidden regions. Mohan, K. V. V., et al. [10] have used sloping line technique to compute Euclidean distance between any two facilities which are Single Convex / Non-convex Polygonal Barier / Forbidden Regions. RavindraNadh.P, etal.[11] have used CRF (coordinate reference frame) technique which avoids searching for solution paths through all vertices and provides quick solution.

However, in all the earlier works the methodologies mentioned above involved made search for optimal location all over the feasible solution space. In the present work it is proposed to apply the concept of Further Reduced Search Area Technique (FRSA) in the presence of mixed forbidden regions. This justifiably reduces the total computation time to 1/10th of what it was in earlier works. These factors made consideration this paper more reasonable. Also, in view of the importance of the consideration of weights, locational problems involving two forbidden regions ellipse and a polygon are considered for brief treatment in this paper. This presentation fills the gap on works leading to development of optimal facility location problems with two mixed forbidden regions ellipse and a polygon.

This undoubtedly improves the effectiveness of the tool and drastically reduces the computational time. This computational tool requires reasonably less memory space in identifying the optimal location of new facility.

An exhaustive review of the literature reveals that no work has ever been reported on locational problems consisting of a combination of an ellipse and a polygonal forbidden region. Numerous works have been reported on locational problems under the influence of forbidden regions, which are circle (s) or polygon(s). Therefore, literature review related to the problem in question could not be appended.

## THE PROBLEM

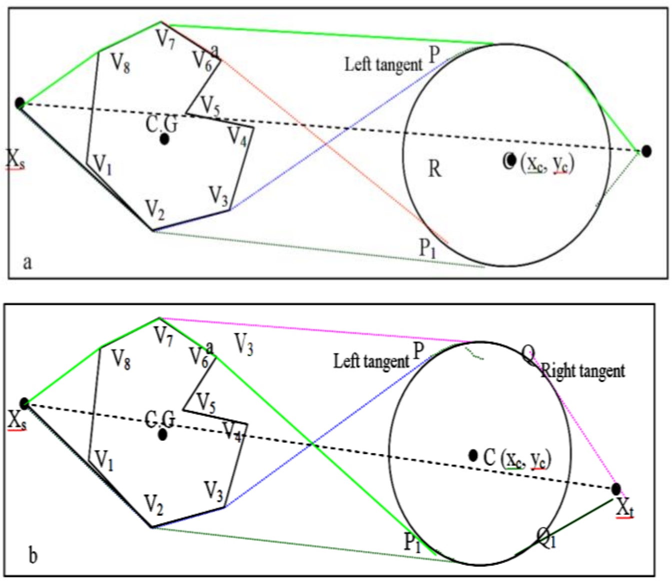
To determine an optimum location of a single new facility Xs in relation to a number of existing interacting facilities Ei, for i = 1,2,…,m in the plane R2, in the presence of two forbidden regions i.e., a convex/non-convex polygonal forbidden regions defined by the sides g(Vk) = 0, for k = 1,…., n, and a single elliptical forbidden region of major axis a1 , minor axis b1 and center Xc which neither permit a location inside nor travel through them, constitutes a classical Weber's single facility location problem Thus this problem becomes a planar location problem with the objective function being non-linear, non-convex and discontinuous with linear constraints of convex/non-convex, elliptical forbidden regions.

### Computation of shortest un-constrained Euclidean path

The problem involves development of procedures that yield un-constrained Euclidean distances between an existing and that of a proposed facility under the influence of barriers / forbidden regions. Before initiating computation of distances it is essential that the proposed facility i.e., a point in the plane R2 is feasible. As the forbidden regions prohibit the location of any facility with in or travel through them, it is desirable to develop feasible/infeasible conditions under all geometric conditions.

### LEMMA 1: CGA Concept for Mixed Forbidden Regions

The shortest un-constrained Euclidean path between a pair of planar points under the influence of two forbidden regions (approximated to an ellipse and a polygon), for location and travel, lies always on the same side of the shortest constrained path (under completely constrained conditions) with respect to the C.G of each of the forbidden regions



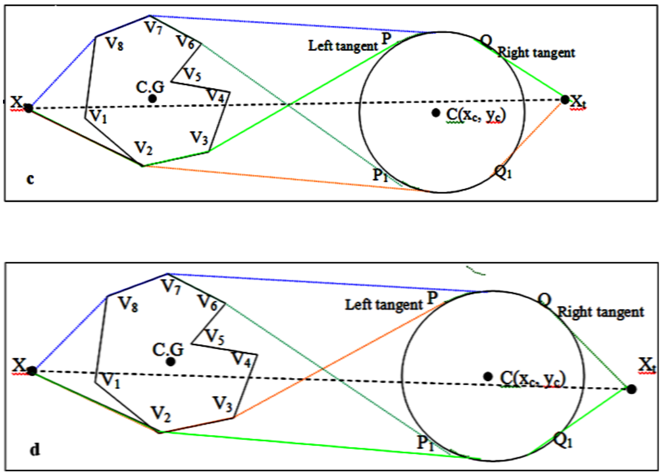



**Figure 1 (a – d) :** represents shortest path identification directly out of the four possible alternate path options under different geometric conditions of constrained $\overline{X_s - X_t}$ line relative to C.G location. Green color path.

Several test cases have been solved to validate the above statement by considering various possible geometric conditions involving an ellipse and a polygonal forbidden region. Almost all cases yielded results that substantiate amply the statement made without any mathematical proof.

The first statement i.e., in cases where the shortest constrained path is in close proximity (0.1 unit) to one or both C.G, despite the fact that the second statement also holds good for the entire range of the solution space, the concept was made use of as a sub-module limiting its application to only about five percent of the searches on account of the requirement of increased number of computations and transient memory space requirements when compared to exclusive C.G based search.

### LEMMA 2: SOD Concept

The shortest un-constrained Euclidean path joining any two planar points in the plane $R^2$, under the influence of a combination of forbidden regions (an ellipse and a polygon) always lies on that side of the ellipse / polygon where the sum of the orthogonal distances (SOD) of the vertices / farthest point on the circumference to the shortest constrained path is minimum.

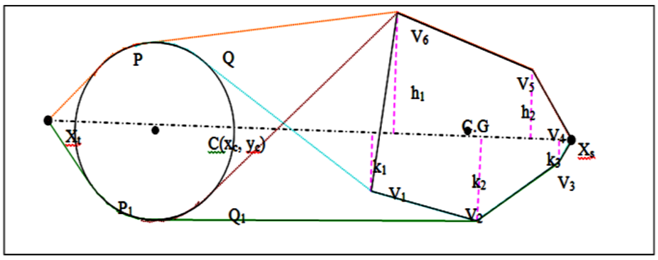



**Figure 2:** Illustrates applicability of SOD method in identifying shortest un-constrained path directly, without having to compute alternate paths.

### LEMMA 3: Further Reduced Search Area

The optimal location of a new facility, with mini-sum criteria, in the plane $R^2$ consisting of a set of interacting existing facilities $E_i$ in the presence of a combination of forbidden regions (an ellipse and a polygon) defined by vertices $V_k$ for k = 1….n, and C center of the ellipse under all geometric conditions falls within 10% of the solution space spread over a square of 5 x 5 units, C.G ($E_i$,g) of the polygon defined by vertices $E_i$, for i = 1,….,m.

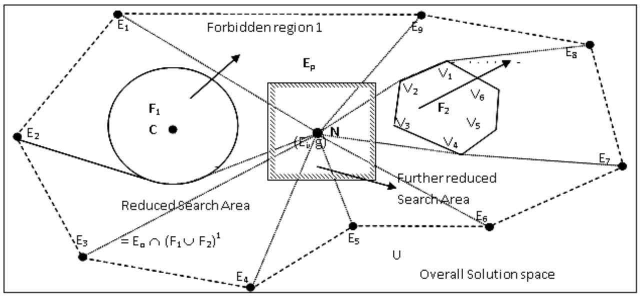



**Figure 3:** Depicting the first and further Search Area confined to a polygonal Reduced area obtained by joining $E_i$.

$E_i$ - Existing Facilities, for i = 1,…m; N - New facility; $F_1$, $F_2$ - Forbidden Regions 1 and 2; $E_p$ – Polygon defined by vertices $E_i$ for i = 1,..,m,; U – Overall solution space; Reduced solution space = $E_p \cap (F_1 \cup F_2)^1$.

The above fig demonstrates the procedure for the identification of ($E_i$, g) graphically. The validity of the statement made under lemma 3 is self-evident. No test cases could be presented as there was no earlier reported work on locational problems with forbidden regions of a combination type.

### MATHEMATICAL FORMULATIONS

Formulation for objective function is

$$\text{Minimize } f(X_s) = \sum_{i=1}^{m} w_i d(X_s, E_i), \text{ for i} = 1,2,.....,\text{m} \qquad (1)$$

Subject to the satisfaction of at least one of the following n linear constraints:-

$$g(V_k) = \begin{Bmatrix} \leq \\ \geq \end{Bmatrix} 0 \qquad \text{for k} = 1,2,.....,\text{n} \qquad (2)$$

$$\text{and } \left[ \{(X_c - X_s)/a\}^2 + \{(Y_c - Y_s)/b\}^2 \right]^{1/2} > 1 \qquad (3)$$

where,

$X_c$ = Location of the center of the elliptical forbidden region $X_c, Y_c$

$a_1$ = Length of major axis of Ellipse

$b_1$ = Length of minor axis of Ellipse

$m$ = no. of existing facilities

$X_s$ = location of new facility (xs, ys)

$E_i$ = location of ith existing facility (xi, yi)

$w_i$ = weight between new facility and ith existing facility

$d(X_s, E_i)$ = The shortest Euclidean un-constrained distance between Xs and Ei

$g(v_k)$ = a set of linear constraints defining the complement of the forbidden region, for k = 1,2,...n

$n$ = no. of vertices of a given convex/non – convex polygonal forbidden region.

The constraints given by equation (2) are established as follows:

(i) Each side of the forbidden region which is a straight line, is represented by the equation,

$$a_k x + b_k y + c_k = 0 \quad \text{for } k = 1,2,.....n \tag{4}$$

(ii) Let ‘ $F_1$ and $F_2$ ’ denote the set of points in the interior of the ellipse and polygonal forbidden regions respectively, i.e., excluding the points on its boundary.

(iii) When any point belonging to set ‘ $F_1, F_2$ ’ is substituted in the expression of the Eq. (3) and (2) it will yield either a positive or a negative value.

If the value is negative then the constraint of the $k^{th}$ side is,

$$a_k x + b_k y + c_k > 0 \tag{4a}$$

If the value is positive, then the constraint of the kth side is,

$$a_k x + b_k y + c_k < 0 \tag{4b}$$

Therefore the constraints that represent all the sides of the forbidden region are given by

$$g(X) = a_k x + b_k y + c_k \begin{Bmatrix} \leq \\ \geq \end{Bmatrix} 0 \tag{4c}$$

## ALGORITHM

Step 1: Input the locations (Cartesian coordinates) of the existing facilities with corresponding weights.

Step 2: Input center C and major and minor axis a,b of the elliptical forbidden region and vertices $V_{jk}$ where k= 1,…$n_j$ for j = 1 of the polygonal forbidden region.

Step 3: Construct a closed polygon by joining all the facilities $E_i$(1…..n) and find C.G $E_i$,g (xfc, yfc) of that polygon considering weights.

Step 4: Check whether the $E_i$,g (xfc, yfc) is feasible or not with polygon or ellipse, if it is feasible then define area A of 5 unit square by considering $E_i$, g as center of the square. Else if it is not feasible with polygon then define area A of 5 unit square; from taking the nearest vertex of that forbidden region as center of the square. Else if it is not feasible with ellipse then define a rectangle of area A, side is taken as half major axis+1 unit from the center of the ellipse and another half minor axis+1unit as one of the corners in which quarter Ei, g is lying.

Step 5: Set l =1 and mindist $D_{min}$ = BIGVALUE (9.99E32)

Step 6: Locate randomly a temporary location $X_s$ for the proposed new facility within the specified area A.

Step 7: Check whether the temporary location of the new facility is feasible or not (i.e., it should be outside the forbidden regions). If the location is feasible then go to next step. Otherwise go to Step 6.

Step 8: Call Hook and Jeeves ($X_s$, $E_i$, D).

Step 9: If D < $D_{min}$ then $X_s$ = $X_{smin}$,, $D_{min}$ = D

Step 10: increment number of iterations i.e l=l+1

Step 11: Check if the l <= number of iterations then Go to Step 6.

Step 12: The optimum distance between temporary location of the new facility $X_{smin}$ and all existing facilities are available in $D_{min}$.

**Sub routine Hook and Jeeves:**

Step 1: Call min path ($X_s$, $E_i$, D)

Step 2: Find new source point $X_{sn}$ by taking a step size a to each direction of $X_s$.

Step 3: Call min-path ($X_{sn}$, $E_i$, $D_n$).

Step 4: If $D_n$ < D, D = $D_n$, Go to Step 2.

Step 5: Find new source point $X_{Sn}$ by taking –a in each direction.

Step 6: Call min-path ($X_{sn}$, $E_i$, $D_n$).

Step 7: If $D_n$ < D, D = $D_n$, Go to Step 5.

Step 8 f (D-$D_n$) < 0.001, then Record $X_{sn}$ as optimum point Else a = a/2 Go to Step 2.

Step 9: Exit

***Sub routine for min-path:***

Step 1: Check whether the direct Euclidean path from source $X_{sn}$ to destination $E_i$ is constrained with polygon/ellipse or not. If constrained go to step 3.

Step 2: Compute the shortest Euclidean distance as $d(X_s, E_i) = \sqrt{(x_s - x_i)^2 + (y_s - y_i)^2}$ go to step 15.

Step 3: If Euclidean path from source $X_s$ and destination $E_i$ is constrained with elliptical forbidden region then Go To step 4. Else Go To step 9.

Step 4: Draw direct path vector $X_s$-$E_i$ from source $X_s$ to destination $E_i$.

Step 5: Establish whether path vector $X_s$-$E_i$ is left/right to the centre of forbidden region.

Step 6: If it is left/right then take left/right tangent from source and calculate the tangent point $X_s$-$E_i$ $(x_i, y_i)$. Calculate $D = D + [(x_i - x_i)^2 + [(y_i - y_i)^2]^{1/2}$ .

Step 7: Calculate the tangent point $DT_1$ $(xt_1, yt_1)$ from destination $E_i$ to the forbidden region by the same side of $X_s$-$E_i(x_i, y_i)$. i.e., left /right.

Step 8: If the path DT to $E_i$ is constrained with polygonal forbidden region, then Go To step 9. Else calculate $D = D + [(xt_1 - x_i)^2 + [(yt_1 - y_i)^2]^{1/2}$ and Go To step 21.

Step 9: Find Centre of Gravity, C.G $(x_g, y_g)$ of 1st forbidden region Take $X_s$-$E_i$ as x-axis, define a new coordinate frame and find new coordinates for all vertex points of forbidden region and C.G.

Step 10: Find left/right with reference to the path vector $X_s$-$E_i$ by taking $y_g <= 0$ then left or if $y_g >= 0$ then right and if $y_g > -0.1$ and $y_g < 0.1$, calculate $R_d$, sum of the perpendicular distances on right side from $L_i(1\ldots a)$ to $X_s$-$E_i$ line & Ld on left side from $R_i(1\ldots b)$ to $X_s$-$E_i$ line. If $L_d >= R_d$ then right else left.

Step 11: Divide vertex coordinates into two groups $L_{i(1\ldots a)}/R_{i(1\ldots b)}$ depending on whether the points are on +y or –y side i.e left/right and sort them on increasing x.

Step 12: Initialize a counter i to 1 to check all the vertices on right/left side.

Step 13: Join S with the $L_i\,(x_{Li}, y_{Li})/R_i\,(x_{Ri}, y_{Ri})$, vertex point on +y/-y side. Define it as x-axis and find coordinates for other vertex points on +y/-y side.

Step 14: If there is no +y/-y vertex point, then, $X_sL_i/X_sR_i$ becomes solution path segment and distance on left/right side is, $D_{(Xs,\ Li/Ri)} = D + \sqrt{\left(x_s - x_{Li/Ri}\right)^2 + \left(y_s - y_{Li/Ri}\right)^2}$

Now, add $L_i/R_i$ to path and shift new source point $X_s$ to $L_i/R_i$. Go to Step 16.

Step 15: Increment i. If i < = a or b then, Go to Step 13.

Step 16: Take $X_s$- $E_i$ as x-axis, define a new coordinate frame and find new coordinates for all +y/-y vertex points.

Step 17: Divide vertex coordinates into two groups depending +y or –y and sort them on increasing x.

Step 18: If there is any point on +y/-y, Go To Step 15. Else path is un-constrained.

Step 19: If new source $X_s$ to target $E_i$ is constrained with circle forbidden region Go To step 4. Else Go To next step.

Step 20: Find the unconstrained Euclidean path distance between the new source $X_s(x_S, y_S)$, and target $E_i(x_i, y_i)$,

$$D(X_s, E_i) = D + \sqrt{(x_s - x_i)^2 + (y_s - y_i)^2}$$

$$d(X_s, E_i) = D(X_s, E_i)$$

Add target point as last solution point on the path.

Step 21: The shortest un-constrained Euclidean distance from source $X_s$ to the destination $E_i$ for any situation is $D(x_s, x_i)$.

Step 22: The above steps are carried for all existing facilities from source to targets and the sum of distance is taken as $f\left(X_s\right) = \Sigma_{i=1}^{m} w_i d\left(X_s, E_i\right)$ for i =1, .,m

## COMPUTATIONAL EXPERIENCE

The FRSA technique has been applied for obtaining optimal solutions to locational problems involving Forbidden regions of two different types of shapes, size and geometric configurations including an ellipse and a polygon. The method developed could provide satisfactory solutions to all the test cases. Necessary care was taken in the development of the logic to obviate possible limitations that the methodology might offer in view of diversity in shape functions.

Numerous test problems with all possible geometric orientations are considered and solved to test the effectiveness of the methodology in providing solutions to problems involving optimum location of a new facility in the presence of a combination of an ellipse and polygonal forbidden regions. The concept of weights introduced in to the present problem; several test problems with different data sets are solved. The results reported are highly encouraging and also reflecting on effectiveness of the tool developed.

The program has been implemented in MATLAB 13 with usual user interface. Various results obtained have been tabulated and presented together with graphic displays for the global optimum.

## TEST CASES

### Test Case with Unit Weight

**Table 1:** Problem data and optimal solution to locational problems involving an ellipse and convex Polygonal forbidden regions.

| **EF** | $E_1$ | $E_2$ | $E_3$ | $E_4$ | $E_5$ | $E_6$ | $E_7$ | $E_8$ | $E_9$ |
|---|---|---|---|---|---|---|---|---|---|
| | (3,8) | (2,4) | (6,1) | (12,2) | (23,2) | (23,5) | (20,12) | (13,11) | (1,12) |
| **FR 1** | Center (x, y) | | Major axis(a) | Minor axis(b) | EF - Number of Existing Facilities; FR 1 – Forbidden region (ellipse) data | | | | |
| | (7, 6) | | 2 | 3 | | | | | |
| **FR 2** | $V_1$ | $V_2$ | $V_3$ | $V_4$ | $V_5$ | FR 2 – Forbidden region (polygon) data | | | |
| | (16,10) | (15,4) | (19,3) | (22,5) | (21,8) | | | | |

| S.No | Optimum Location With Unit Weights | | Function Value |
|---|---|---|---|
| | X | Y | |
| 1 | 11.74444 | 4.833333 | 88.55721 |
| 2 | 11.64444 | 4.833333 | 88.56183 |
| 3 | 11.69444 | 4.833333 | 88.5582 |
| 4 | 11.69444 | 4.883333 | 88.54304 |
| 5 | 11.69444 | 4.933333 | 88.53099 |
| 6 | 11.69444 | 4.983333 | 88.52205 |
| **7** | **11.69444** | **5.033333** | **88.5162** |
| 8 | 11.59444 | 5.183333 | 88.52683 |
| 9 | 11.59444 | 5.133333 | 88.52349 |
| 10 | 11.59444 | 4.783333 | 88.58639 |
| **GOV** | **11.69444** | **5.033333** | **88.5162** |

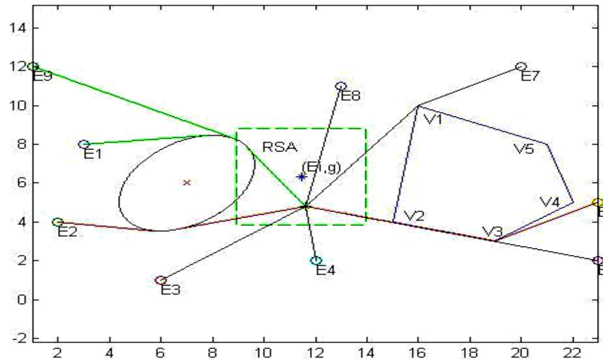



**Figure 7:** Graphical Display of Optimum Location along with shortest un-constrained Euclidean paths, for problems with unit weight, obtained using the data from the table 1.

### Locational Problems with weights

To study the behavior of solutions under varying interacting frequencies with a set of existing facilities including that of proposed new facility the factor $w_i$ representing frequency of interaction has been introduced in to the problem definition.

### Test case with weights

**Table2:** Problem data and optimal solution to locational problems involving an ellipse and convex Polygonal forbidden regions with weights.

| EF | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 |
|---|---|---|---|---|---|---|---|---|---|
| | (3,8) | (2,4) | (6,1) | (12,2) | (23,2) | (23,5) | (20,12) | (13,11) | (1,12) |
| **FR 1** | Center (x, y) | | Major axis(a) | Minor axis(b) | EF - Number of Existing Facilities; FR 1 – Forbidden region (ellipse) data | | | | |
| | (7, 6) | | 2 | 3 | | | | | |
| **FR 2** | V1 | V2 | V3 | V4 | V5 | FR 2 – Forbidden region (polygon) data | | | |
| | (16,10) | (15,4) | (19,3) | (22,5) | (21,8) | | | | |
| **Weights** | 0.1 | 0.1 | 0.0 | 0.45 | 0.05 | 0.2 | 0.0 | 0.05 | 0.05 |

| S.No | Optimum Location With Weights | | Function Value With Unit Weights | Function Value With Given Weights |
|---|---|---|---|---|
| | X | Y | | |
| 1 | 12.3 | 3.25 | 88.55721 | 87.43399 |
| 2 | 12.3 | 3.3 | 88.56183 | 87.34982 |
| 3 | 12.3 | 3.35 | 88.55820 | 87.26768 |
| 4 | 12.3 | 3.55 | 88.54304 | 86.95938 |
| 5 | 12.3 | 3.75 | 88.53099 | 86.68355 |
| 6 | 12.3 | 3.85 | 88.52205 | 86.55787 |
| 7 | 12.3 | 3.95 | 88.51620 | 86.44040 |
| 8 | 12.3 | 4.05 | 88.52683 | 86.33118 |
| 9 | 12.3 | 4.35 | 88.52349 | 86.05345 |
| **10** | **12.3** | **4.55** | **88.58639** | **85.91038** |
| **GOV** | **12.3** | **4.55** | **88.58639** | **85.91038** |

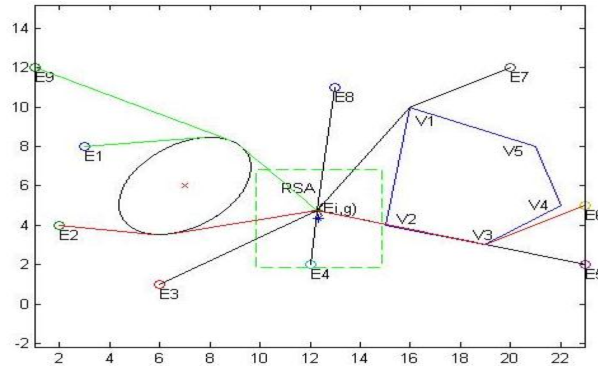



**Figure 8:** Graphical Display of Optimum Location along with shortest un-constrained Euclidean paths, for problems with weights, obtained using the data shown in Table 2

## RESULTS AND DISCUSSIONS

The discontinuous and non-convex property in optimal location of a new facility in the presence of elliptical and polygonal forbidden regions is complex in nature. The Hooke and Jeeves discrete search technique is unified to the methodology which mainly simplifies this very reason. Under normal circumstances though randomized seed point generation search for optimum location is made throughout the feasible discontinuous solution space, this procedure provides local optimums scattered over the feasible solution space. From among these local optimums a global optimum is identified.

The methodology developed to determine the shortest un-constrained Euclidean distance between any two planar locations under the influence of two forbidden regions approximated to an ellipse and a convex / non-convex polygon has successfully been integrated in to the overall dynamic locational search. Development of a mathematical model that can deal with two different sets of linear and non-linear expressions while optimizing the objective function would be typically complicated. Graphical method (Heuristic) developed can yield solutions to problem in question, though the solutions thus obtained may not be unique and exact. The results obtained are highly encouraging as they are observed to be totally agreeing with the expected values on validation. The success experienced in dealing with locational problems involving a set of two different types of forbidden regions can easily been extended to problems with more than two (multiple) forbidden regions. Several test cases are taken and solved with and without weights. As it is practically infeasible to include all such solutions only a few typical test cases are listed and discussed. However, they could not be validated as no published work in this area has been reported hither to.

Lot of reported works depicted many ways of overcoming the optimal facility location problems in presence of polygonal and circular forbidden regions. The present work makes an insight into real time application of the works done as the forbidden regions may not always be geometrically defined. This work delivers a more efficient way of handling real time problems in various diligences where the forbidden regions may be approximately depicted as an ellipse.

In addition to the constricted search space, logistic costs incurred in distribution and resource handling is reduced. The actual applications of present work include optimization of handling and distribution costs of resources in mining or establishments which include forbidden regions like mountains ,lakes, pits etc., . It also helps in establishment of new facility in an optimal position so that feasibility in reaching is simplified. As said before, reduction of costs help in increased efficiency of path identification and serves the purpose resourcefully.

The method applied have also led to a reduction of 90% search time, saved substantial memory space requirements. A study of the solution characteristic amply reveals the influence of weights over the proposed new facility location. All the optimal locations demonstrate this phenomenon of skewing towards those existing facilities that have higher weight distributions.

Apart from the advantages, there is a limitation on the flexibility of the solution being obtained. Limitations of this work include lack of cognizance in identification of other available optimal locations outside Further Reduced Search Area which rarely occur. This limitation seldom effects efficiency of facility location.

Further, the distance norm considered is Euclidean all through but easily the methodologies developed so far can suitably be modified to accommodate rectilinear distance norm or general lp-norm, which would reasonably enhance the domain of potential applications.

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