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Manufacturing Facilities Layout Design

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Abstract - *This paper presents a facilities layout problem. Here in this problem we consider placing departments in a given total area. We use the quantitative technique to solve the layout problem. It considers the load that moves among the facilities and the distances the load has to travel. Minimizing the load distance travelled is the most important objective in layout problems. The problem was mathematically modelled and solved using LINGO software.*

Key Words: Distance, Facilities Layout, LINGO, Load.

1. INTRODUCTION

Facilities location problem also known as location analysis is a branch of operations research and computational geometry concerned with minimizing the total distance travelled. A simple facility location problem is the Weber problem where the location of facilities is based on the minimization of the weighted sum of distances from the given point sites. More complex problems consider the placement of multiple facilities and constraints to the location of facilities. The basic formulation consists of a set of facilities sites and the demand that must be satisfied. The goal is to pick the facilities such that the demand of the facilities is to minimize the distance from each demand point to that facility and the opening cost of the facilities.The facility location problem is NP hard. A number of algorithms have been developed to solve them. Dynamic facility location problems consider a time dependent plan for positioning the facilities while serving the customers in a particular region or area. This class of problems emerge when changes in demand and transportation cost are known. There are two facility location problem types capacitated and uncapacitated problems.

2. LITERATURE REVIEW

Mahendra Singh [1] had done a review of the facility location designs offering better productivity. Vivekanand S Gogi et al [2] have done a simulation of the current and proposed layout using ARENA software. Gyorvy Kovacs and Sebastin Kot [3] have redesigned a layout. S M Kadane and S G Bhatwadekar[4] have optimized using simulation, manufacturing facilities layout. M R Jadhav et al [5] have made facility layout design improvements in an industry. Anand Jayakumar A and Krishnaraj C [6] have created a mathematical revenue model for multiple customer segments. Anand Jayakumar A et al [7] have optimized a p median problem using python. Anand Jayakumar A et al [8] have optimized a fixed charge problem using python. Anand Jayakumar A and Krishnaraj C [9] have created a mathematical model for pricing and revenue management of perishable assets. Anand Jayakumar A and Krishnaraj C [10] have suggested on implementation of quality circle. Anand Jayakumar A et al [11] have suggested a mixed strategy for aggreage planning. Anand Jayakumar A et al [12] have created a mathematical model for aggregate planning. Anand Jayakumar A et al [13] have created a mathematical model for supply chain network design. Anand Jayakumar A et al [14] have created a mathematical model for aggregate planning for a pump manufacturing company. Anand Jayakumar A et al [15] have improved productivity in a stitching section. Anand Jayakumar A et al [16] have created another model for aggregate planning. Anand Jayakumar A et al [17] have reviewed on the mathematical models for supply chain network design. Anand Jayakumar A et al [18] have created a chase strategy for aggregate production planning. Anand Jayakumar A and Krishnaraj C [19] have created a mathematical model for supply chain network optimization using gravity location method. Krishnaraj C et al [20] have solved a supply chain network optimization model.

3. THE MATHEMATICAL MODEL

Let Xik = 1 if facility i is allotted to site k and Xjl = 1 if facility j is allotted to site l.

Each facility goes to exactly one site and each site gets exactly one facility. These are given by

$\sum_{i=1}^{n} Xij = 1$ for every j

$\sum_{j=1}^{n} Xij = 1$ for every i

Xij = 0,1

Given Xik and Xjl their contribution to Z is XikXjkwijdkl. The objective function is therefore,

Minimize $\sum_{i=1}^{n} \sum_{j=1}^{n} \sum_{k=1}^{n} \sum_{l=1}^{n} wij * dkl * Xik * Xjl$

The above problem has a quadratic objective function and the usual assignment constraints and is called the Quadratic Assignment Problem. It is not a linear Integer Programming problem, but is a quadratic problem. It is a difficult problem to solve.

4. THE PROBLEM

Consider a problem of relatively locating 4 facilities in four sites. The load matrix (in tons) among the four facilities is given in Table 1 below.

Table-1: Load matrix

	1	2	3	4
1	-	3	7	4
2		-	6	5
3			-	2
4				-

The loads are assumed to be symmetric and wij = wji.

We assume that the facilities require equal area (and of same shape) and the four sites are shown in Fig 1 below (marked site 1 to site 4).

1	2
3	4

Fig-1: A layout for the illustration

Considering the given layout, the distance among the sites is given in Table 2 below (as a multiple of unit distance).

Table-2: Distance Matrix

	1	2	3	4
1	-	1	1	2
2		-	2	1
3			-	1
4				-

The distances are rectilinear distance and not Euclidean.

5. SYSTEM CONFIGURATION

The problem was solved in a system with Windows 10 operating system. Intel i7 8th generation processor was used with 16 GB RAM. LINGO version 12 software package was used for solving the problem as shown in Fig 2 below.

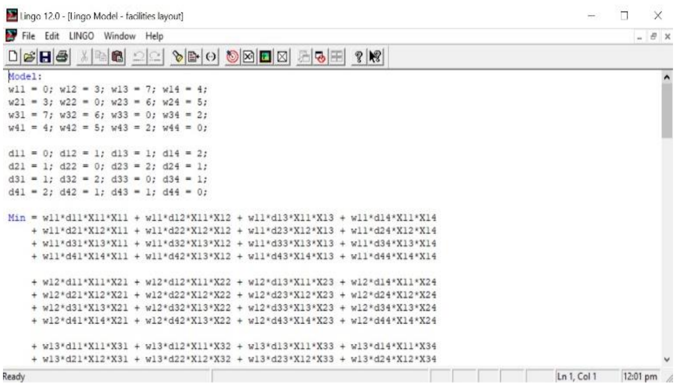

Fig-2: LINGO Software.

6. LINGO

LINGO is a simple tool for solving linear and nonlinear optimization problems and also to analyze them. Optimization problems are generally classified into linear and nonlinear problems based on the relationship with the variables whether it is linear or nonlinear. LINGO uses a set of built in solvers to solve a wide variety of problems. Local solvers are used to solve till a local optima in reached. There may be a number of local optima. The Global solver converts the original non-convex, nonlinear problem into several convex, linear sub problems. Then, it uses the branch-and-bound technique to exhaustively search over these sub problems for the global solution.

7. LINGO PROGRAM

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Model:
w11 = 0; w12 = 3; w13 = 7; w14 = 4;
w21 = 3; w22 = 0; w23 = 6; w24 = 5;
w31 = 7; w32 = 6; w33 = 0; w34 = 2;
w41 = 4; w42 = 5; w43 = 2; w44 = 0;

d11 = 0; d12 = 1; d13 = 1; d14 = 2;
d21 = 1; d22 = 0; d23 = 2; d24 = 1;
d31 = 1; d32 = 2; d33 = 0; d34 = 1;
d41 = 2; d42 = 1; d43 = 1; d44 = 0;

Min = w11*d11*X11*X11 + w11*d12*X11*X12 +
w11*d13*X11*X13 + w11*d14*X11*X14
  + w11*d21*X12*X11 + w11*d22*X12*X12 +
w11*d23*X12*X13 + w11*d24*X12*X14
  + w11*d31*X13*X11 + w11*d32*X13*X12 +
w11*d33*X13*X13 + w11*d34*X13*X14
  + w11*d41*X14*X11 + w11*d42*X13*X12 +
w11*d43*X14*X13 + w11*d44*X14*X14

  + w12*d11*X11*X21 + w12*d12*X11*X22 +
w12*d13*X11*X23 + w12*d14*X11*X24
  + w12*d21*X12*X21 + w12*d22*X12*X22 +
w12*d23*X12*X23 + w12*d24*X12*X24
  + w12*d31*X13*X21 + w12*d32*X13*X22 +
w12*d33*X13*X23 + w12*d34*X13*X24
  + w12*d41*X14*X21 + w12*d42*X13*X22 +
w12*d43*X14*X23 + w12*d44*X14*X24

  + w13*d11*X11*X31 + w13*d12*X11*X32 +
w13*d13*X11*X33 + w13*d14*X11*X34
  + w13*d21*X12*X31 + w13*d22*X12*X32 +
w13*d23*X12*X33 + w13*d24*X12*X34
  + w13*d31*X13*X31 + w13*d32*X13*X32 +
w13*d33*X13*X33 + w13*d34*X13*X34
  + w13*d41*X14*X31 + w13*d42*X13*X32 +
w13*d43*X14*X33 + w13*d44*X14*X34

  + w14*d11*X11*X41 + w14*d12*X11*X42 +
w14*d13*X11*X43 + w14*d14*X11*X44
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+ w14*d21*X12*X41 + w14*d22*X12*X42 + w14*d23*X12*X43 + w14*d24*X12*X44
+ w14*d31*X13*X41 + w14*d32*X13*X42 + w14*d33*X13*X43 + w14*d34*X13*X44
+ w14*d41*X14*X41 + w14*d42*X13*X42 + w14*d43*X14*X43 + w14*d44*X14*X44

+ w21*d11*X21*X11 + w21*d12*X21*X12 + w21*d13*X21*X13 + w21*d14*X21*X14
+ w21*d21*X22*X11 + w21*d22*X22*X12 + w21*d23*X22*X13 + w21*d24*X22*X14
+ w21*d31*X23*X11 + w21*d32*X23*X12 + w21*d33*X23*X13 + w21*d34*X23*X14
+ w21*d41*X24*X11 + w21*d42*X23*X12 + w21*d43*X24*X13 + w21*d44*X24*X14

+ w22*d11*X21*X21 + w22*d12*X21*X22 + w22*d13*X21*X23 + w22*d14*X21*X24
+ w22*d21*X22*X21 + w22*d22*X22*X22 + w22*d23*X22*X23 + w22*d24*X22*X24
+ w22*d31*X23*X21 + w22*d32*X23*X22 + w22*d33*X23*X23 + w22*d34*X23*X24
+ w22*d41*X24*X21 + w22*d42*X23*X22 + w22*d43*X24*X23 + w22*d44*X24*X24

+ w23*d11*X21*X31 + w23*d12*X21*X32 + w23*d13*X21*X33 + w23*d14*X21*X34
+ w23*d21*X22*X31 + w23*d22*X22*X32 + w23*d23*X22*X33 + w23*d24*X22*X34
+ w23*d31*X23*X31 + w23*d32*X23*X32 + w23*d33*X23*X33 + w23*d34*X23*X34
+ w23*d41*X24*X31 + w23*d42*X23*X32 + w23*d43*X24*X33 + w23*d44*X24*X34

+ w24*d11*X21*X41 + w24*d12*X21*X42 + w24*d13*X21*X43 + w24*d14*X21*X44
+ w24*d21*X22*X41 + w24*d22*X22*X42 + w24*d23*X22*X43 + w24*d24*X22*X44
+ w24*d31*X23*X41 + w24*d32*X23*X42 + w24*d33*X23*X43 + w24*d34*X23*X44
+ w24*d41*X24*X41 + w24*d42*X23*X42 + w24*d43*X24*X43 + w24*d44*X24*X44

+ w31*d11*X31*X11 + w31*d12*X31*X12 + w31*d13*X31*X13 + w31*d14*X31*X14
+ w31*d21*X32*X11 + w31*d22*X32*X12 + w31*d23*X32*X13 + w31*d24*X32*X14
+ w31*d31*X33*X11 + w31*d32*X33*X12 + w31*d33*X33*X13 + w31*d34*X33*X14
+ w31*d41*X34*X11 + w31*d42*X33*X12 + w31*d43*X34*X13 + w31*d44*X34*X14

+ w32*d11*X31*X21 + w32*d12*X31*X22 + w32*d13*X31*X23 + w32*d14*X31*X24
+ w32*d21*X32*X21 + w32*d22*X32*X22 + w32*d23*X32*X23 + w32*d24*X32*X24
+ w32*d31*X33*X21 + w32*d32*X33*X22 + w32*d33*X33*X23 + w32*d34*X33*X24
+ w32*d41*X34*X21 + w32*d42*X33*X22 + w32*d43*X34*X23 + w32*d44*X34*X24

+ w33*d11*X31*X31 + w33*d12*X31*X32 + w33*d13*X31*X33 + w33*d14*X31*X34
+ w33*d21*X32*X31 + w33*d22*X32*X32 + w33*d23*X32*X33 + w33*d24*X32*X34
+ w33*d31*X33*X31 + w33*d32*X33*X32 + w33*d33*X33*X33 + w33*d34*X33*X34
+ w33*d41*X34*X31 + w33*d42*X33*X32 + w33*d43*X34*X33 + w33*d44*X34*X34

+ w34*d11*X31*X41 + w34*d12*X31*X42 + w34*d13*X31*X43 + w34*d14*X31*X44
+ w34*d21*X32*X41 + w34*d22*X32*X42 + w34*d23*X32*X43 + w34*d24*X32*X44
+ w34*d31*X33*X41 + w34*d32*X33*X42 + w34*d33*X33*X43 + w34*d34*X33*X44
+ w34*d41*X34*X41 + w34*d42*X33*X42 + w34*d43*X34*X43 + w34*d44*X34*X44

+ w41*d11*X41*X11 + w41*d12*X41*X12 + w41*d13*X41*X13 + w41*d14*X41*X14
+ w41*d21*X42*X11 + w41*d22*X42*X12 + w41*d23*X42*X13 + w41*d24*X42*X14
+ w41*d31*X43*X11 + w41*d32*X43*X12 + w41*d33*X43*X13 + w41*d34*X43*X14
+ w41*d41*X44*X11 + w41*d42*X43*X12 + w41*d43*X44*X13 + w41*d44*X44*X14

+ w42*d11*X41*X21 + w42*d12*X41*X22 + w42*d13*X41*X23 + w42*d14*X41*X24
+ w42*d21*X42*X21 + w42*d22*X42*X22 + w42*d23*X42*X23 + w42*d24*X42*X24
+ w42*d31*X43*X21 + w42*d32*X43*X22 + w42*d33*X43*X23 + w42*d34*X43*X24
+ w42*d41*X44*X21 + w42*d42*X43*X22 + w42*d43*X44*X23 + w42*d44*X44*X24

+ w43*d11*X41*X31 + w43*d12*X41*X32 + w43*d13*X41*X33 + w43*d14*X41*X34
+ w43*d21*X42*X31 + w43*d22*X42*X32 + w43*d23*X42*X33 + w43*d24*X42*X34
+ w43*d31*X43*X31 + w43*d32*X43*X32 + w43*d33*X43*X33 + w43*d34*X43*X34
+ w43*d41*X44*X31 + w43*d42*X43*X32 + w43*d43*X44*X33 + w43*d44*X44*X34

+ w44*d11*X41*X41 + w44*d12*X41*X42 + w44*d13*X41*X43 + w44*d14*X41*X44
+ w44*d21*X42*X41 + w44*d22*X42*X42 + w44*d23*X42*X43 + w44*d24*X42*X44
+ w44*d31*X43*X41 + w44*d32*X43*X42 + w44*d33*X43*X43 + w44*d34*X43*X44
+ w44*d41*X44*X41 + w44*d42*X43*X42 + w44*d43*X44*X43 + w44*d44*X44*X44;

X11 + X21 + X31 + X41 = 1;
X12 + X22 + X32 + X42 = 1;

```
X13 + X23 + X33 + X43 = 1;
X14 + X24 + X34 + X44 = 1;

X11 + X12 + X13 + X14 = 1;
X21 + X22 + X23 + X24 = 1;
X31 + X32 + X33 + X34 = 1;
X41 + X42 + X43 + X44 = 1;

@BIN(X11);@BIN(X12);@BIN(X13);@BIN(X14);
@BIN(X21);@BIN(X22);@BIN(X23);@BIN(X24);
@BIN(X31);@BIN(X32);@BIN(X33);@BIN(X34);
@BIN(X41);@BIN(X42);@BIN(X43);@BIN(X44);
End
```

8. RESULT AND DISCUSSION

- Facility 1 is allocated to site 4.
- Facility 2 is allocated to site 1.
- Facility 3 is allocated to site 2.
- Facility 4 is allocated to site 3.

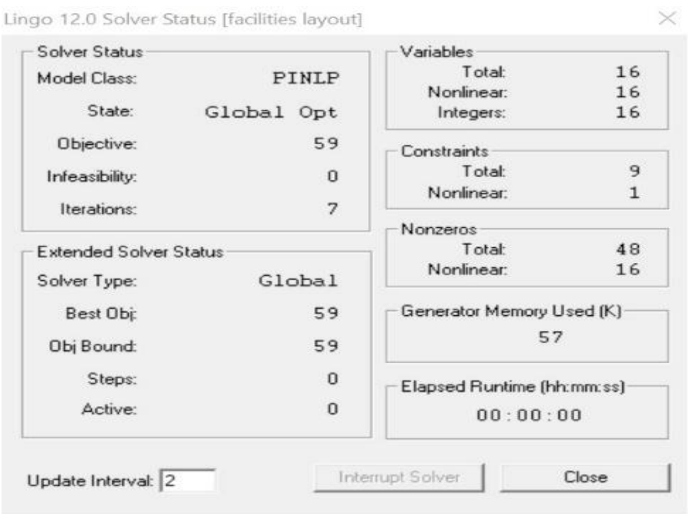

Fig-3: Result in LINGO

A global optimum of Rs 59 was obtained as shown in Fig 4.

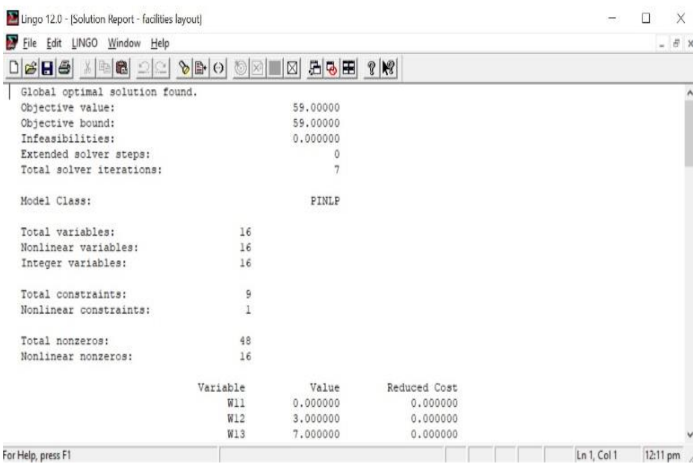

Fig-4: Final solution.

9. CONCLUSION

Thus we have solved the manufacturing facilities design problem.

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