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The Computer Programs of Layout Methods Based on Decision Making Theory

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Synopsis

We tried to look at the allocation techniques in plant layout from the point of view of decision making theory. And it was made clear that Laplace, Minimax and Hurwicz princilpe can be applied to the allocation techniques. The techniques based on these principles were called Laplace method, Minimax method and Hurwicz method.

In this paper algorithms and computer programs of these methods were described in order to solve the layout problems effectively.

1. Introduction

The allocation technique plays the important roll in facility plant layout. The basic allocation techniques determine the allocation based on distance between locations, and volume transported between departments. The process of the allocation of department to location is just the decision making.

The authors attempt to look at the basic allocation techniques from the point of view of decision making theory [1,2,3]. Though many principles are applied to the allocation techniques, it is made

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clear that Laplace principle, Minimax principle, and Hurwicz princilpe are useful for allocation techniques. The allocation techniques based on these principles are called Laplace method, Minimax method, and Hurwicz method[4]. They are described in the latter.

2. Algorithm of allocation technique

2.1 Notation of allocation problem

n = number of departments = number of locations

I_i = location

$I = \{ I_1, I_2, \ldots, I_n \}$ = set of locations

B_i = department

$B = \{ B_1\ B_2, \ldots, B_n \}$ = set of departments

d_{ij} = distance between I_i and I_j

where $d_{ij} = d_{ji}$, $d_{ii} = 0.0$

v_{ij} = volume transported from B_i to B_j

where $v_{ij} = v_{ji}$, $v_{ii} = 0.0$

$i, j = 1, 2, \ldots, n$

$EV = \sum_{i<j} \sum_{j=1}^{n} d_{ij} \cdot v_{s(i)s(j)}$ = evaluated value of determined allocation

where $s(i)$ and $s(j)$ are the department numbers which are allocated to the location I_i and I_j.

2.2 Laplace method

Laplace method based on Laplace principle is as follows.

1. Assume that each location or each department is assigned equal probability of allocation. That is,

   $P(I_i) = 1/n$, $P(B_i) = 1/n$, $i = 1,2,\ldots,n.$

2. The allocation criterion
   To select from among possible departments or locations, expected utility of each department and of each location are calculated as follows.

$$EI_i = \sum_{j=1}^{n} d_{ij}/(n-1) \quad , \quad EB_i = \sum_{j=1}^{n} v_{ij}/(n-1) \quad , \ i=1,2,\ldots,n$$

3. The allocation

   Arrange EI_i in ascending order and EB_i in descending order.

$$EI_{k(1)} < EI_{k(2)} < \ldots < EI_{k(j)} < \ldots < EI_{k(n)}$$

$$EB_{l(1)} > EB_{l(2)} > \ldots > EB_{l(j)} > \ldots > EB_{l(n)}$$

   And relate $EI_{k(j)}$ with $EB_{l(j)}$, $j=1,2,\ldots,n$.

   From this relations allocate the department $B_{l(j)}$ to the location $I_{k(j)}$. And calculate the evaluated value (EV) of this allocation.

2.3 Minimax method

Minimax method based on Minimax principle is as follows.

1. The allocation criterion

   For any m, minimax value of location and maximin value of department are selected from d_{ij} and v_{ij} as follows.

$$D(I_{k(m)}) = \min_{i} \max_{j \neq i} d_{ij} \ , \ I_{k(m)} \varepsilon\ I - \{I_{k(1)},\ldots,I_{k(m-1)}\}$$

$$\text{where } i,j \ \varepsilon\ \{1,2,\ldots,n\} - \{k(1),k(2),\ldots,k(m-1)\}$$

$$M(B_{l(m)}) = \max_{i} \min_{j \neq i} v_{ij} \ , \ B_{l(m)} \varepsilon\ B - \{B_{l(1)},\ldots,B_{l(m-1)}\}$$

$$\text{where } i,j \ \varepsilon\ \{1,2,\ldots,n\} - \{l(1),l(2),\ldots,l(m-1)\}$$

2. The allocation

   From $D(I_{k(m)})$ and $M(B_{l(m)})$ allocate the department $B_{l(m)}$ to the location $I_{k(m)}$.

   $m = 1, 2, \ldots, n$. And calculate the evaluated value.

2.4 Hurwicz method

Hurwicz method based on Hurwicz principle is as follows.

1. The allocation criterion

   First maximum and minimum value of location and department are selected from d_{ij} and v_{ij} as follows.

$$MAXI_i = \max_{1\leq j\leq n} d_{ij} \quad , \quad MINI_i = \min_{1\leq j\leq n} d_{ij}$$

$$MAXB_i = \max_{1\leq j\leq n} v_{ij} \quad , \quad MINB_i = \min_{1\leq j\leq n} v_{ij}$$

$$i = 1, 2, ..., n.$$

Second α is defined as the index of the relative optimism and pessimism. The criterions are calculated from α, $MAXI_i$, $MINI_i$, $MAXB_i$ and $MINB_i$ as follows.

$$DI_i = \alpha \cdot MINI_i + (1-\alpha)\cdot MAXI_i$$

$$DB_i = \alpha \cdot MINB_i + (1-\alpha)\cdot MAXB_i$$

$$i = 1, 2, ..., n.$$

2. The allocation

   Arrange DI_i in ascending order and DB_i in descending order.

$$DI_{k(1)} < DI_{k(2)} < ... < DI_{k(j)} < ... < DI_{k(n)}$$

$$DB_{l(1)} > DB_{l(2)} > ... > DB_{l(j)} > ... > DB_{l(n)}$$

   Relate $DI_{k(j)}$ with $DB_{l(j)}$, j=1,2,...,n.

   From this relations allocate the department $B_{l(j)}$ to the location $I_{k(j)}$. And calculate the evaluated value $EV(\alpha)$ of this location.

3. α is changed from 0.0 to 1.0 by 0.1. For each α, the allocation of the evaluated value $EV(\alpha)$ is determined. And finally select the allocation of minimum evaluated value $EV(\alpha_0)$ from among them.

3. Computer program

Laplace method, Minimax method, and Hurwicz method are programmed in Fortran IV and the forms of subroutine. Subroutine names are LAPLAC, MINMAX and HURWIT.

```
SUBROUTINE LAPLAC(NDIM,NVD,POS,DEP,SDEP,EV)
SUBROUTINE MINMAX(NDIM,NVD,POS,DEP,SDEP,EV)
SUBROUTINE HURWIT(NDIM,NVD,POS,DEP,SDEP,EV,SALPHA)
```

These programs are shown in Table 1, Table 2 and Table 3.

3.1 Argument list

The same arguments except SALPHA in HURWIT are used in these subroutines.

ARGUMENT	I/O	TYPE	SIZE	DEFINITION
NDIM	INPUT	INTEGER	1	number of departments
NVD	INPUT	REAL	50 x 50	distance and volume matrix
POS	INPUT	nonnumerical	50	location name (A4)
DEP	INPUT	nonnumerical	50	department name (A4)
SDEP	OUTPUT	nonnumerical	50	rearranged department name according to the allocation (A4)
EV	OUTPUT	REAL	1	evaluated value of the allocation
SALPHA	OUTPUT	REAL	1	index of optimism in HURWIT

3.2 Suggestion on using

3.2.1 NDIM $\leqq$ 40

3.2.2 Correspondence between arguments and given data.

NDIM = n , n : number of departments

NVD(i,j) = a_{ij} , $a_{ij} = v_{ij}$ for $i < j$

$a_{ij} = d_{ij}$ for $i > j$

$a_{ij} = 0.0$ for $i = j$

POS(i) = II_i , II_i : location name to indicate location I_i. (A4)

DEP(i) = BB_i , BB_i : department name to indicate department B_i. (A4)

SDEP(i) = $BB_{m(i)}$, $BB_{m(i)}$: determined allocation of department $BB_{m(i)}$ to location II_i. (A4)

3.2.3 SALPHA is only used in HURWIT and is value of α in the case of minimum EV(α).

3.2.4 Subroutine MINA, MAXI and SUB1 are used in LAPLAC and HURWIT. MINA is used to arrange values of distance and volume in ascending order. MAXI is used to arrange these values in descending order. And SUB1 is used to rearrange $B_{l(j)}$ to $B_{m(i)}$ and to calculate the evaluated value of the allocation.

4. Example

The data of n = 4 problem given by R.J.Reed[5] are used to check the programs. Given data are shown in Table 4. And results are shown in Table 5.

References

[1] H.L.Timms and M.F.Pohlen : "The Production Function in Business", Richard D. Irwin Inc.,(1970),69.

[2] I.Horowitz : "An Introduction to Quantitive Business Analysis", McGrow-Hill Book Co.,(1965),81.

[3] A.Moriya : "Operations Research", Nihon Riko Shuppankai Ltd.,(1973),250,(in Japanease).

[4] Y.Fujiwara, H.Osaki and S.Kikuchi, Proceedings of 1975 Spring Conference of JIMA, No.163,(in Japanease).

[5] R.Jr.Reed : "Plant Location, Layout and Maintenance", Richard D. Irwin Inc.,(1970),84.

Table 1, Program Listing of LAPLAC

```
      SUBROUTINE  LAPLAC(NDIM,NVD,POS,DEP,SDEP,EV)
      DIMENSION  NVD(40,40),POS(40),DEP(40),DMEAN(40),
       DMM(40,2),PMM(40,2),PMEAN(40),SDEP(40)
      REAL  NVD,KSUM,JSUM
      WRITE(6,1000)
 1000 FORMAT(1H1,///,10X,25H***  LAPLACE  METHOD  ***,////)
      KPOS=1
  101 KSUM=0
      K1=KPOS
      K2=1
  102 IF(K1-K2)  103,104,103
  103 KSUM=KSUM+NVD(K1,K2)
  104 IF(K2-KPOS)  105,106,106
  105 K2=K2+1
      GO  TO  102
  106 K1=K1+1
      IF(K1-NDIM)  107,107,108
  107 CONTINUE
      GO  TO  102
  108 PMEAN(KPOS)=KSUM/FLOAT(NDIM-1)
      KPOS=KPOS+1
      IF(KPOS-NDIM)  101,101,109
  109 CONTINUE
      WRITE(6,1010)
 1010 FORMAT(1H0,4X,33HEXPECTATION (EI) OF EACH POSITION)
      WRITE(6,1011)
 1011 FORMAT(1H0,10X,10HPOSITION  , 7X,2HEI)
      DO  10  I=1,NDIM
      WRITE(6,1012)  POS(I),PMEAN(I)
 1012 FORMAT(1H ,12X,A4,5X,E15.7)
   10 CONTINUE
      JDEP=1
  201 JSUM=0
      J1=1
      J2=JDEP
  202 IF(J1-J2)  203,204,203
  203 JSUM=JSUM+NVD(J1,J2)
  204 IF(J1-JDEP)  205,206,206
  205 J1=J1+1
      GO  TO  202
  206 J2=J2+1
      IF(J2-NDIM)  207,207,208
  207 CONTINUE
      GO  TO  202
  208 DMEAN(JDEP)=JSUM/FLOAT(NDIM-1)
      JDEP=JDEP+1
      IF(JDEP-NDIM)  201,201,209
  209 CONTINUE
      WRITE(6,2010)
 2010 FORMAT(1H0,//,5X,35HEXPECTATION (EB) OF EACH DEPARTMENT)
      WRITE(6,2011)
 2011 FORMAT(1H0,10X,10HDEPARTMENT, 7X,2HEB)
```

```
      DO  20  I=1,NDIM
      WRITE(6,2012)  DEP(I),DMEAN(I)
 2012 FORMAT(1H ,12X,A4,5X,E15.7)
   20 CONTINUE
      CALL  MINA(NDIM,PMEAN,PMM)
      CALL  MAXI(NDIM,DMEAN,DMM)
      DO  30  I=1,NDIM
      IPMM=PMM(I,2)
      PMEAN(I)=POS(IPMM)
      IDMM=DMM(I,2)
      DMEAN(I)=DEP(IDMM)
   30 CONTINUE
      WRITE(6,4000)
 4000 FORMAT(1H0,///,15X,21H+++ LAYOUT AND EV +++)
      CALL SUB1(NDIM,NVD,POS,DEP,PMM,DMM,SDEP,EV)
      RETURN
       END



      SUBROUTINE  MINA(N,B,BB)
C      ROTATION  FROM MIN  TO  MAX
      DIMENSION  B(40),BB(40,2)
      NN=N-1
      DO  1  J=1,N
      BB(J,1)=B(J)
      BB(J,2)=J
    1 CONTINUE
      DO  2  I=1,NN
      II=I+1
      DO  3  J=II,N
      IF(BB(I,1)-BB(J,1))  3,3,4
    4 BX1=BB(I,1)
      BX2=BB(I,2)
      BB(I,1)=BB(J,1)
      BB(I,2)=BB(J,2)
      BB(J,1)=BX1
      BB(J,2)=BX2
    3 CONTINUE
    2 CONTINUE
      RETURN
      END


      SUBROUTINE  MAXI(N,A,AA)
C     ROTATION  FROM  MAX  TO  MIN
      DIMENSION  A(40),AA(40,2)
      NN=N-1
      DO  1  J=1,N
      AA(J,1)=A(J)
      AA(J,2)=J
    1 CONTINUE
      DO  2  I=1,NN
      II=I+1
      DO  3  J=II,N
      IF(AA(I,1)-AA(J,1))  4,3,3
    4 AX1=AA(I,1)
      AX2=AA(I,2)
```

```
      AA(I,1)=AA(J,1)
      AA(I,2)=AA(J,2)
      AA(J,1)=AX1
      AA(J,2)=AX2
    3 CONTINUE
    2 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE  SUB1(NDIM,NVD,POS,DEP,PMM,DMM,SDEP,EV)
      DIMENSION  NVD(40,40),POS(40),DEP(40),PMM(40,2),DMM(40,2),SDEP(40)
      REAL  NVD
      LDIM=NDIM-1
      DO  1  I=1,LDIM
      II=I+1
      DO  1  J=II,NDIM
      IF(PMM(I,2)-PMM(J,2))  1,1,2
    2 PZ1=PMM(I,1)
      PZ2=PMM(I,2)
      DZ1=DMM(I,1)
      DZ2=DMM(I,2)
      PMM(I,1)=PMM(J,1)
      PMM(I,2)=PMM(J,2)
      DMM(I,1)=DMM(J,1)
      DMM(I,2)=DMM(J,2)
      PMM(J,1)=PZ1
      PMM(J,2)=PZ2
      DMM(J,1)=DZ1
      DMM(J,2)=DZ2
    1 CONTINUE
      DO  3  I=1,NDIM
      ND=DMM(I,2)
      SDEP(I)=DEP(ND)
    3 CONTINUE
      WRITE(6,1010)
 1010 FORMAT(1H0, //,10X,10HPOSITION  ,5X,10HDEPARTMENT)
      DO  7  I=1,NDIM
      WRITE(6,1020)  POS(I),SDEP(I)
 1020 FORMAT(1H ,12X,A4,11X,A4)
    7 CONTINUE
      EV=0.0
      DO  4  I=1,LDIM
      II=I+1
      DO  4  J=II,NDIM
      ND1=DMM(I,2)
      ND2=DMM(J,2)
      IF(ND1-ND2)  5,6,6
    6 NDT=ND1
      ND1=ND2
      ND2=NDT
    5 EV=EV+NVD(ND1,ND2)*NVD(J,I)
    4 CONTINUE
      WRITE(6,1040)  EV
 1040 FORMAT(1H0,///,10X,5HEV = ,E15,7,///)
      RETURN
      END
```

Table 2, Program Listing of MINMAX

```
      SUBROUTINE  MINMAX(NDIM,NVD,POS,DEP,SDEP,EV)
      DIMENSION  NVD(40,40),NNVD(40,40),POS(40),DEP(40),
     -SDEP(40),MPOS(40),MDEP(40),MAXI(40),MINB(40),INDEX(40)
      REAL  NVD,NNVD,IMAX,MAXI,IMIN,JMIN,MINB,JMAX
C     MINIMAX PRINCIPLE OF LAYOUT PROBLEM
      WRITE(6,1000)
 1000 FORMAT(1H1,///,10X,25H***  MINIMAX  METHOD  ***,////)
      DO  1  I=1,NDIM
        INDEX(I)=I
      DO  1  J=I,NDIM
      NNVD(J,I)=NVD(J,I)
      NNVD(I,J)=NVD(J,I)
    1 CONTINUE
C     CALCULATION OF MINMAX OF POSITION
      WRITE(6,1001)
 1001 FORMAT(1H0,4X,43HCALCULATION OF MINMAX PROCEDURE OF POSITION)
      WRITE(6,1002)
 1002 FORMAT(1H0,26X,8HMIN(MAX),8X,10HPOSITION  )
      J1=1
  100 CONTINUE
      DO  2  I=1,NDIM
      IMAX=0
      DO  3  J=1,NDIM
      IF(IMAX.GE.NNVD(I,J))  GO  TO  3
      IMAX=NNVD(I,J)
    3 CONTINUE
      MAXI(I)=IMAX
    2 CONTINUE
      DO  110  I=1,NDIM
      IF(MAXI(I).NE.0.0)GO  TO  120
  110 CONTINUE
      DO  130  IX=1,NDIM
      IF(INDEX(IX).EQ.0)  GO  TO  130
      MPOS(J1)=IX
  130 CONTINUE
      GO  TO  140
  120 IMIN=1.0E+50
      DO  4  K=1,NDIM
      IF(MAXI(K).LE.0.0)GO  TO  4
      IF(IMIN.LE.MAXI(K))  GO  TO  4
      IMIN=MAXI(K)
      MPOS(J1)=K
    4 CONTINUE
      L=MPOS(J1)
      INDEX(L)=0
       DO  5  K2=1,NDIM
      NNVD(L,K2)=0
      NNVD(K2,L)=0
    5 CONTINUE
      WRITE(6,1003) J1,IMIN,POS(L)
 1003 FORMAT(1H ,8X,6H(STEP ,I2,1H),5X,E15.7,8X,A4)
      J1=J1+1
```

```
      IF(J1.LE.NDIM)  GO  TO  100
  140 CONTINUE
      MPS=MPOS(J1)
      WRITE(6,1003)  J1,IMIN,POS(MPS)
C     MATRIX  OF  VOLUME
      DO  6  I=1,NDIM
      INDEX(I)=I
      DO  6  J=I,NDIM
      NNVD(I,J)=NVD(I,J)
      NNVD(J,I)=NVD(I,J)
    6 CONTINUE
C     CALCULATION  OF  MINMAX  OF  VOLUME
      WRITE(6,1004)
 1004 FORMAT(1H0,//,5X,45HCALCULATION OF MAXMIN PROCEDURE OF DEPARTMENT)
      WRITE(6,1005)
 1005 FORMAT(1H0,26X,8HMAX(MIN),8X,10HDEPARTMENT)
      JJ1=1
  200 CONTINUE
      DO  7  I=1,NDIM
      JMIN=1.0E50
      DO  8  J=1,NDIM
      IF(I.EQ.J)  GO  TO  8
      IF(JMIN.LE.NNVD(I,J))  GO  TO  8
      JMIN=NNVD(I,J)
    8 CONTINUE
      MINB(I)=JMIN
    7 CONTINUE
      DO  150  JZ=1,NDIM
      IF(MINB(JZ).NE.1.0E+50)  GO  TO  160
  150 CONTINUE
      DO  170  JX=1,NDIM
      IF(INDEX(JX).EQ.0)  GO  TO  170
      MDEP(JJ1)=JX
  170 CONTINUE
      GO  TO  180
  160 JMAX=0
      DO  9  M=1,NDIM
      IF(MINB(M).EQ.1.0E+50)  GO  TO  9
       IF(JMAX.GT.MINB(M))  GO  TO  9
      JMAX=MINB(M)
      MDEP(JJ1)=M
    9 CONTINUE
      LL=MDEP(JJ1)
      INDEX(LL)=0
      DO  10  M1=1,NDIM
      NNVD(LL,M1)=1.0E+50
      NNVD(M1,LL)=1.0E+50
   10 CONTINUE
      WRITE(6,1003)  JJ1,JMAX,DEP(LL)
      JJ1=JJ1+1
      IF(JJ1.LE.NDIM)  GO  TO  200
  180 CONTINUE
      MDP=MDEP(JJ1)
      WRITE(6,1003)  JJ1,JMAX,DEP(MDP)
C     CALCULATION OF EV
      NN=NDIM-1
      DO  11  I=1,NN
      II=I+1
      DO  11  J=II,NDIM
      IF(MPOS(I).LE.MPOS(J))  GO  TO  11
      IP=MPOS(I)
```

```
      ID=MDEP(I)
      MPOS(I)= MPOS(J)
      MDEP(I)= MDEP(J)
      MPOS(J)=IP
      MDEP(J)=ID
   11 CONTINUE
      DO  12   I=1,NDIM
      ND=MDEP(I)
      SDEP(I)=DEP(ND)
   12 CONTINUE
      WRITE(6,4000)
 4000 FORMAT(1H0,///,15X,21H+++ LAYOUT AND EV +++)
      WRITE(6,1008)
 1008 FORMAT(1H0, //,10X,10HPOSITION   ,5X,10HDEPARTMENT)
      DO  15   I=1,NDIM
      WRITE(6,1009)  POS(I),SDEP(I)
 1009 FORMAT(1H ,12X,A4,11X,A4)
   15 CONTINUE
      EV=0,0
      DO  13   I=1,NN
      II=I+1
      DO  13   J=II,NDIM
      ND1=MDEP(I)
      ND2=MDEP(J)
      IF(ND1,LT,ND2)  GO  TO  14
      NDT=ND1
      ND1=ND2
      ND2=NDT
   14 EV=EV+NVD(ND1,ND2)*NVD(J,I)
   13 CONTINUE
      WRITE(6,1010)  EV
 1010 FORMAT(1H0,///,10X,5HEV = ,E15.7,///)
      RETURN
      END
```

Table 3, Program Listing of HURWIT

```
      SUBROUTINE  HURWIT(NDIM,NVD,POS,DEP,SDEP,EV,SALPHA)
C     HURWITZ  METHOD
      DIMENSION  NVD(40,40),POS(40),DEP(40),DMAX(40),DMIN(40),
     - DMM(40,2),PMM(40,2),PMAX(40),PMIN(40),PDI(40),DDI(40),
     - SDEP(40),SSDEP(40)
      REAL  NVD,JMAX,JMIN,KMAX,KMIN
      WRITE(6,2010)
 2010 FORMAT(1H1,///,10X,25H***  HURWICZ  METHOD  ***,////)
      JDEP=1
  100 JMAX=-1.0E+50
      JMIN=1.0E+50
      J1=1
      J2=JDEP
  500 IF(J1.EQ.J2)  GO  TO  200
      IF(JMAX.LT.NVD(J1,J2))  JMAX=NVD(J1,J2)
      IF(JMIN.GT.NVD(J1,J2))  JMIN=NVD(J1,J2)
  200 IF(J1-JDEP)  300,400,400
  300 J1=J1+1
      GO  TO  500
  400 J2=J2+1
      IF(J2.GT.NDIM)  GO  TO  600
      GO  TO  500
  600 DMAX(JDEP)=JMAX
      DMIN(JDEP)=JMIN
      JDEP=JDEP+1
      IF(JDEP.LE.NDIM)  GO  TO  100
      KPOS=1
  101 KMAX=-1.0E+50
      KMIN=1.0E+50
      K1=KPOS
      K2=1
  301 IF(K1.EQ.K2)  GO  TO  201
      IF(KMAX.LT.NVD(K1,K2)) KMAX=NVD(K1,K2)
       IF(KMIN.GT.NVD(K1,K2)) KMIN=NVD(K1,K2)
  201 IF(K2-KPOS)  401,501,501
  401 K2=K2+1
      GO  TO  301
  501 K1=K1+1
      IF(K1.GT.NDIM)  GO  TO  601
      GO  TO  301
  601 PMAX(KPOS)=KMAX
      PMIN(KPOS)=KMIN
      KPOS=KPOS+1
      IF(KPOS.LE.NDIM)  GO  TO  101
      WRITE(6,1000)
 1000 FORMAT(1H0,4X,44HMAXIMUM(MAXI) AND MINIMUM (MINI) OF DISTANCE)
      WRITE(6,1001)
 1001 FORMAT(1H0,10X,10HPOSITION   ,5X,4HMAXI,13X,4HMINI)
      DO  10  I=1,NDIM
      WRITE(6,2001)  POS(I),PMAX(I),PMIN(I)
 2001 FORMAT(1H ,12X,A4,5X,E15.7,3X,E15.7)
   10 CONTINUE
```

```
      WRITE(6,1002)
 1002 FORMAT(1H0,//,5X,43HMAXIMUM(MAXB) AND MINIMUM(MINB) OF VOLUME   )
      WRITE(6,1003)
 1003 FORMAT(1H0,10X,10HDEPARTMENT,5X,4HMAXB,13X,4HMINB)
      DO  11  I=1,NDIM
      WRITE(6,2001)  DEP(I),DMAX(I),DMIN(I)
   11 CONTINUE
      ALPHA=0.0
      EV=1.0E+50
  103  DO  102  I=1,NDIM
      PDI(I)=ALPHA*PMIN(I)+(1.0-ALPHA)*PMAX(I)
       DDI(I)=ALPHA*DMAX(I)+(1.0-ALPHA)*DMIN(I)
  102 CONTINUE
      WRITE(6,2004)  ALPHA
 2004 FORMAT(1H0, 6X,8HALPHA = ,F4.1)
      WRITE(6,3000)
 3000 FORMAT(1H0,15X,43HDETERMINATIONS OF POSITIONS AND DEPARTMENTS)
      WRITE(6,2005)
 2005 FORMAT(1H0,10X,10HPOSITION  ,5X,2HPI,12X,10HDEPARTMENT,5X,2HDI)
      DO  12  I=1,NDIM
      WRITE(6,2006)  POS(I),PDI(I),DEP(I),DDI(I)
 2006 FORMAT(1H ,12X,A4,5X,E15.7,5X,A4,5X,E15.7)
   12 CONTINUE
      WRITE(6,4000)
 4000 FORMAT(1H0,///,15X,21H+++ LAYOUT AND EV +++)
      CALL  MINA(NDIM,PDI,PMM)
      CALL  MAXI(NDIM,DDI,DMM)
      CALL   SUB1(NDIM,NVD,POS,DEP,PMM,DMM,SSDEP,SEV)
      IF(EV.LE.SEV)  GO  TO  700
      EV=SEV
      SALPHA=ALPHA
      DO  701  I=1,NDIM
      SDEP(I)=SSDEP(I)
  701 CONTINUE
  700 ALPHA=ALPHA+0.1
      IF(ALPHA.LE.1.0)  GO  TO  103
      WRITE(6,4000)
      WRITE(6,4002) SALPHA
 4002 FORMAT(1H0,///,10X,8HALPHA = ,F5.2,///)
      WRITE(6,2007)
 2007 FORMAT(1H0,10X,10HPOSITION  ,5X,10HDEPARTMENT)
      DO  13  I=1,NDIM
      WRITE(6,2008)  POS(I),SDEP(I)
 2008 FORMAT(1H ,12X,A4,11X,A4)
   13 CONTINUE
      WRITE(6,2009)  EV
 2009 FORMAT(1H0,///,10X,5HEV = ,E15.7)
      RETURN
      END
```

Table 4. Given data

Distance and volume matrix

$a_{11} = 0.0$, $a_{22} = 0.0$, $a_{33} = 0.0$, $a_{44} = 0.0$

$a_{12} = v_{12} = 55.0$	$a_{21} = d_{21} = 42.0$
$a_{13} = v_{13} = 135.0$	$a_{31} = d_{31} = 14.0$
$a_{14} = v_{14} = 50.0$	$a_{41} = d_{41} = 22.0$
$a_{23} = v_{23} = 95.0$	$a_{32} = d_{32} = 30.0$
$a_{24} = v_{24} = 82.0$	$a_{42} = d_{42} = 20.0$
$a_{34} = v_{34} = 130.0$	$a_{43} = d_{43} = 10.0$

Location name(A4)	Department name(A4)
II_1 = I 1	BB_1 = B 1
II_2 = I 2	BB_2 = B 2
II_3 = I 3	BB_3 = B 3
II_4 = I 4	BB_4 = B 4

Number of departments

$n = 4$

Table 5, Computer Output

5.1, Output of LAPLAC

*** LAPLACE METHOD ***

EXPECTATION (EI) OF EACH POSITION

POSITION	EI
I 1	0,2600000E 02
I 2	0,3066666E 02
I 3	0,1800000E 02
I 4	0,1733333E 02

EXPECTATION (EB) OF EACH DEPARTMENT

DEPARTMENT	EB
B 1	0,8000000E 02
B 2	0,7733333E 02
B 3	0,1200000E 03
B 4	0.8733333E 02

+++ LAYOUT AND EV +++

POSITION	DEPARTMENT
I 1	B 1
I 2	B 2
I 3	B 4
I 4	B 3

EV = 0.1164000E 05

5.2, Output of MINMAX

```
*** MINIMAX METHOD ***


CALCULATION OF MINMAX PROCEDURE OF POSITION

                      MIN(MAX)           POSITION
(STEP  1)        0.2200000E 02          I 4
(STEP  2)        0.3000000E 02          I 3
(STEP  3)        0.4200000E 02          I 1
(STEP  4)        0.4200000E 02          I 2


CALCULATION OF MAXMIN PROCEDURE OF DEPARTMENT

                      MAX(MIN)           DEPARTMENT
(STEP  1)        0.9500000E 02          B 3
(STEP  2)        0.5500000E 02          B 2
(STEP  3)        0.5000000E 02          B 4
(STEP  4)        0.5000000E 02          B 1


      +++ LAYOUT AND EV +++


POSITION          DEPARTMENT
   I 1               B 4
   I 2               B 1
   I 3               B 2
   I 4               B 3


EV =    0.1140800E 05
```

5.3, Output of HURWIT

```
*** HURWICZ METHOD ***


MAXIMUM(MAXI) AND MINIMUM (MINI) OF DISTANCE

POSITION          MAXI                  MINI
   I 1          0,4200000E 02         0,1400000E 02
   I 2          0,4200000E 02         0,2000000E 02
   I 3          0,3000000E 02         0,1000000E 02
   I 4          0,2200000E 02         0,1000000E 02


MAXIMUM(MAXB) AND MINIMUM(MINB) OF VOLUME

DEPARTMENT        MAXB                  MINB
   B 1          0.1350000E 03         0,5000000E 02
   B 2          0,9500000E 02         0.5500000E 02
   B 3          0,1350000E 03         0,9500000E 02
   B 4          0,1300000E 03         0,5000000E 02


     +++ LAYOUT AND EV +++


ALPHA =  0.00


POSITION        DEPARTMENT
   I 1             B 1
   I 2             B 4
   I 3             B 2
   I 4             B 3


EV =   0.1185000E 05
```