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 princible 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
principle 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

\[ n = \text{number of departments} = \text{number of locations} \]
\[ I_i = \text{location} \]
\[ I = \{ I_1, I_2, \ldots, I_n \} = \text{set of locations} \]
\[ B_i = \text{department} \]
\[ B = \{ B_1, B_2, \ldots, B_n \} = \text{set of departments} \]
\[ d_{ij} = \text{distance between } I_i \text{ and } I_j \]
where \[ d_{ij} = d_{ji}, \quad d_{ii} = 0.0 \]
\[ v_{ij} = \text{volume transported from } B_i \text{ to } B_j \]
where \[ v_{ij} = v_{ji}, \quad v_{ii} = 0.0 \]
\[ i, j = 1, 2, \ldots, n \]
\[ EV = \sum_{i<j} \sum_{j=1}^{n} d_{ij} \cdot v_{s(i)s(j)} = \text{evaluated value of determined} \]
\[ \text{allocation} \]
\[ \text{where } s(i) \text{ and } s(j) \text{ are the department numbers} \]
\[ \text{which are allocated to the location } I_i \text{ and } I_j. \]

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,
\[ P(I_i) = 1/n, \quad P(B_i) = 1/n, \quad i = 1, 2, \ldots, n. \]

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.
3. The allocation

Arrange $E_{I_i}$ in ascending order and $E_{B_j}$ in descending order.

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

$E_{B_{z(1)}} > E_{B_{z(2)}} > ... > E_{B_{z(j)}} > ... > E_{B_{z(n)}}$

And relate $E_{I_{k(j)}}$ with $E_{B_{z(j)}}$, $j = 1, 2, ..., n$.

From these relations, allocate the department $B_{z(j)}$ 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.

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

where $i, j \in \{1, 2, ..., n\} - \{k(1), k(2), ..., k(m-1)\}$

$M(B_{z(m)}) = \max_{i} \min_{j \neq i} v_{ij}$, $B_{z(m)} \in B - \{B_{z(1)}, ..., B_{z(m-1)}\}$

where $i, j \in \{1, 2, ..., n\} - \{z(1), z(2), ..., z(m-1)\}$

2. The allocation

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

$m = 1, 2, ..., n$. 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.
Second $\alpha$ is defined as the index of the relative optimism and pessimism. The criterions are calculated from $\alpha$, $\text{MAX}_i$, $\text{MIN}_i$, $\text{MAX}_B$, and $\text{MIN}_B$ as follows.

$$
\text{DI}_i = \alpha \cdot \text{MIN}_i + (1-\alpha) \cdot \text{MAX}_i \\
\text{DB}_i = \alpha \cdot \text{MIN}_B + (1-\alpha) \cdot \text{MAX}_B
$$

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

2. The allocation

Arrange $\text{DI}_i$ in ascending order and $\text{DB}_i$ in descending order.

$$
\text{DI}_k(1) < \text{DI}_k(2) < \ldots < \text{DI}_k(j) < \ldots < \text{DI}_k(n) \\
\text{DB}_j(1) > \text{DB}_j(2) > \ldots > \text{DB}_j(j) > \ldots > \text{DB}_j(n)
$$

Relate $\text{DI}_k(j)$ with $\text{DB}_j(j)$, $j = 1, 2, \ldots, n$.

From this relations allocate the department $B_j(j)$ to the location $I_k(j)$. And calculate the evaluated value $\text{EV}(\alpha)$ of this location.

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

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

3.2 Suggestion on using

3.2.1 NDIM ≤ 40
3.2.2 Correspondence between arguments and given data.

\[
NDIM = n, \quad n: \text{number of departments}
\]
\[
NVD(i,j) = a_{ij}, \quad a_{ij} = v_{ij} \quad \text{for} \quad i < j
\]
\[
a_{ij} = d_{ij} \quad \text{for} \quad i > j
\]
\[
a_{ij} = 0.0 \quad \text{for} \quad i = j
\]
\[
POS(i) = II_i, \quad II_i: \text{location name to indicate location I}_i. (A4)
\]
\[
DEP(i) = BB_i, \quad BB_i: \text{department name to indicate department B}_i. (A4)
\]
\[
SDEP(i) = BB_{m(i)}, \quad BB_{m(i)}: \text{determined allocation of department B}_{m(i)} to location II_i. (A4)
\]

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 SUBl 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 SUBl is used to rearrange B_i(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

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+NVO(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(1H1,///,10X.33HEXPECTATION (EI) OF EACH POSITION)
    WRITE(6,1011)
1011 FORMAT(1H1,///,10X,10HPOSITION \ 7X.2HEI)
    DO 10 I=1,NDIM
        WRITE(6,1012) POS(I),PMEAN(I)
1012 FORMAT(1H12X.A4.5X.E15.7)
    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(1H1,///,5X,35HEXPECTATION (EB) OF EACH DEPARTMENT)
    WRITE(6,2011)
2011 FORMAT(1H1,///,10X,10HDEPARTMENT \ 7X,2HEB)
DO 20 I=1,NDIM
WRITE(6,2012) DEP(I),DMEAN(I)
20 CONTINUE
CALL MINA(NDIM,PMEAN,PMM)
CALL MAXI(NDIM,DMEAN,DMM)
DO 30 I=1,NDIM
PMM=PMM(I,2)
PMEAN(I)=POS(IPMM)
DMM=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)) 3,3,3
4 AX1=AA(I,1)
AX2=AA(I,2)
3 CONTINUE
2 CONTINUE
RETURN
END
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\begin{align*}
A(AJ) &= AA(J) \\
A(AJ) &= AA(J) \\
A(J) &= AX1 \\
A(J) &= AX2
\end{align*}

\begin{verbatim}
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
   J=I+1
   IF(PMM(I,2)-PMM(J,2) 1,1,2
   1 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)=PZ1
   PMM(J,2)=PZ2
   DMM(J,1)=DZ1
   DMM(J,2)=DZ2
2 CONTINUE
   DO 3 I=1,NDIM-1
      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(1H0, //,12X,A4,11X,A4)
7 CONTINUE
   EV=0.0
   DO 4 I=1,LDIM
      J=I+1
      ND1=DMM(I,2)
      ND2=DMM(J,2)
      IF(ND1-ND2) 5,6,6
5 EV=EV+NVD(ND1,ND2)*NVD(J,1)
   4 CONTINUE
WRITE(6,1040) EV
1040 FORMAT(1H0, //,10X,5HEV = ,E15.7, //)
RETURN
END
\end{verbatim}

\begin{align*}
A(AJ) &= AA(J) \\
A(AJ) &= AA(J) \\
A(J) &= AX1 \\
A(J) &= AX2
\end{align*}
Table 2, Program Listing of MINMAX

SUBROUTINE MINMAXCNDIM,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,MAXI,MINI,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)=NNVD(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=I,NDIM
    IF(IMAX.GE.NNVD(I,J)) GO TO 3
    IMAX=NNVD(I,J)
  3 CONTINUE
  MAXI(I)=IMAX
  CONTINUE
2 CONTINUE
DO 110 I=1,NDIM
  IF(INDEX(I).EQ.0) GO TO 130
  MPOS(I)=I
  INDEX(I)=I
  DO 5 K2=1,NDIM
    NNVD(L,K2)=0
  5 CONTINUE
  WRITE(6,1003) J1,MINI,P0S(L)
1003 FORMAT(1H8X,6H(STEP ,12,1H),5X,E15.7,8X,A4)
J1=J1+1
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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=1,NDIM
NNVD(I,J)=NVD(I,J)
6 CONTINUE

C CALCULATION OF MINMAX OF VOLUME
WRITE(6,1004)
1004 FORMAT(1HO.//,5X,45HCALCULATION OF MAXMIN PROCEDURE OF DEPARTMENT)
WRITE(6,1005)
1005 FORMAT(1HO.26X.8HMAX(MIN),8X.10HDEPARTMENT)
JJ1=1
200 CONTINUE
DO 7 J=1,NDIM
JMIN=1.0E50
DO 8 J=1,NDIM
IF(JMIN.LE.NNVD(I,J)) GO TO 8
JMIN=NNVD(I,J
8 CONTINUE
MINB(I)=JMIN
7 CONTINUE
DO 150 J2=1,NDIM
IF(MINB(J2),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(1HO,///,15X,21H+++ LAYOUT AND EV +++)
WRITE(6,1008)
1008 FORMAT(1HO, ///,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(1HO,///,10X,5HEV = ,E15.7,///)
RETURN
END
Table 3, Program Listing of HURWIT

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

C HURWITZ METHOD
DIMENSION NVD(40,40), POS(40), DEP(40), DMAX(40), DMIN(40),
  SDEP(40), SSSDEP(40)
REAL NVD, JMAX, JMIN, KMAX, KMIN

WRITE(6, 2010)
 2010 FORMAT(1HL///, 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(J1.LT.NVD(J1,J2)) JMAX=NVD(J1,J2)
      IF(J2.LT.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(K1.LT.NVD(K1,K2)) KMAX=NVD(K1,K2)
      IF(K2.LT.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(1HO, 4X, 44HMAXIMUM(MAX), AND MINIMUM (MIN) OF DISTANCE)
      WRITE(6, 1001)
    1001 FORMAT(1HO, 10X, 10HPOSITION, 5X, 4HMAXI, 13X, 4HMINI)
      DO 10 I = 1, NDIM
        WRITE(6, 1001) POS(I), PMAX(I), PMIN(I)
    2001 FORMAT(1H, 12X, A4, 5X, E15.7, 3X, E15.7)
    10 CONTINUE
```
WRITE(6,1002)
1002 FORMAT(1HO,/,5X,43HMAXIMUM(MAXB) AND MINIMUM(MINB) OF VOLUME)
WRITE(6,1003)
1003 FORMAT(1HO,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(1HO,6X,8HALPHA=F4.1)
WRITE(6,3000)
3000 FORMAT(1HO,15X,43HDETERMINATIONS OF POSITIONS AND DEPARTMENTS)
WRITE(6,2005)
2005 FORMAT(1HO,10X,10HPOSITION,5X,2HPD,12X,10HDEPARTMENT,5X,2HDD)
DO 12 I=1,NDIM
WRITE(6,2006) POS(I),PDI(I),DEP(I),DDI(I)
12 CONTINUE
WRITE(6,4000)
4000 FORMAT(1HO,/,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(1HO,/,10X,8HALPHA=F5.2,///)
WRITE(6,2007)
2007 FORMAT(1HO,10X,10HPOSITION,5X,10HDEPARTMENT)
DO 13 I=1,NDIM
WRITE(6,2008) POS(I),SDEP(I)
13 CONTINUE
WRITE(6,2009) EV
2009 FORMAT(1HO,///,10X,5HEV=E15.7)
RETURN
END
Table 4. Given data

Distance and volume matrix

<table>
<thead>
<tr>
<th>i</th>
<th>j</th>
<th>a_{ij}</th>
<th>v_{ij}</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>0.0</td>
<td>55.0</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>0.0</td>
<td>135.0</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>0.0</td>
<td>50.0</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>0.0</td>
<td>95.0</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>0.0</td>
<td>82.0</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>0.0</td>
<td>130.0</td>
</tr>
</tbody>
</table>

Location name (A4) | Department name (A4)

<table>
<thead>
<tr>
<th>i</th>
<th>j</th>
<th>Location name (A4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>I1</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>I2</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>I3</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>I4</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>BB1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>BB2</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>BB3</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>BB4</td>
</tr>
</tbody>
</table>

Number of departments

n = 4
Table 5, Computer Output

5.1, Output of LAPLAC

*** LAPLACE METHOD ***

**EXPECTATION (EI) OF EACH POSITION**

<table>
<thead>
<tr>
<th>POSITION</th>
<th>EI</th>
</tr>
</thead>
<tbody>
<tr>
<td>I 1</td>
<td>0.260000E 02</td>
</tr>
<tr>
<td>I 2</td>
<td>0.306666E 02</td>
</tr>
<tr>
<td>I 3</td>
<td>0.180000E 02</td>
</tr>
<tr>
<td>I 4</td>
<td>0.173333E 02</td>
</tr>
</tbody>
</table>

**EXPECTATION (EB) OF EACH DEPARTMENT**

<table>
<thead>
<tr>
<th>DEPARTMENT</th>
<th>EB</th>
</tr>
</thead>
<tbody>
<tr>
<td>B 1</td>
<td>0.800000E 02</td>
</tr>
<tr>
<td>B 2</td>
<td>0.773333E 02</td>
</tr>
<tr>
<td>B 3</td>
<td>0.120000E 03</td>
</tr>
<tr>
<td>B 4</td>
<td>0.873333E 02</td>
</tr>
</tbody>
</table>

+++ LAYOUT AND EV +++

<table>
<thead>
<tr>
<th>POSITION</th>
<th>DEPARTMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>I 1</td>
<td>B 1</td>
</tr>
<tr>
<td>I 2</td>
<td>B 2</td>
</tr>
<tr>
<td>I 3</td>
<td>B 4</td>
</tr>
<tr>
<td>I 4</td>
<td>B 3</td>
</tr>
</tbody>
</table>

EV = 0.1164000E 05
5.2. Output of MINMAX

*** MINIMAX METHOD ***

**CALCULATION OF MINMAX PROCEDURE OF POSITION**

<table>
<thead>
<tr>
<th>MIN(MAX)</th>
<th>POSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2200000E 02 I 4</td>
<td>I 4</td>
</tr>
<tr>
<td>0.3000000E 02 I 3</td>
<td>I 3</td>
</tr>
<tr>
<td>0.4200000E 02 I 1</td>
<td>I 1</td>
</tr>
<tr>
<td>0.4200000E 02 I 2</td>
<td>I 2</td>
</tr>
</tbody>
</table>

**CALCULATION OF MAXMIN PROCEDURE OF DEPARTMENT**

<table>
<thead>
<tr>
<th>MAX(MIN)</th>
<th>DEPARTMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.9500000E 02 B 3</td>
<td>B 3</td>
</tr>
<tr>
<td>0.5500000E 02 B 2</td>
<td>B 2</td>
</tr>
<tr>
<td>0.5000000E 02 B 4</td>
<td>B 4</td>
</tr>
<tr>
<td>0.5000000E 02 B 1</td>
<td>B 1</td>
</tr>
</tbody>
</table>

+++ LAYOUT AND EV +++

<table>
<thead>
<tr>
<th>POSITION</th>
<th>DEPARTMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>I 1</td>
<td>B 4</td>
</tr>
<tr>
<td>I 2</td>
<td>B 1</td>
</tr>
<tr>
<td>I 3</td>
<td>B 2</td>
</tr>
<tr>
<td>I 4</td>
<td>B 3</td>
</tr>
</tbody>
</table>

EV = 0.1140800E 05
5.3, Output of HURWIT

*** HURWICZ METHOD ***

MAXIMUM (MAXI) AND MINIMUM (MINI) OF DISTANCE

<table>
<thead>
<tr>
<th>POSITION</th>
<th>MAXI</th>
<th>MINI</th>
</tr>
</thead>
<tbody>
<tr>
<td>I 1</td>
<td>0.4200000E +02</td>
<td>0.1400000E +02</td>
</tr>
<tr>
<td>I 2</td>
<td>0.4200000E +02</td>
<td>0.2000000E +02</td>
</tr>
<tr>
<td>I 3</td>
<td>0.3000000E +02</td>
<td>0.1000000E +02</td>
</tr>
<tr>
<td>I 4</td>
<td>0.2200000E +02</td>
<td>0.1000000E +02</td>
</tr>
</tbody>
</table>

MAXIMUM (MAXB) AND MINIMUM (MINB) OF VOLUME

<table>
<thead>
<tr>
<th>DEPARTMENT</th>
<th>MAXB</th>
<th>MINB</th>
</tr>
</thead>
<tbody>
<tr>
<td>B 1</td>
<td>0.1350000E +03</td>
<td>0.5000000E +02</td>
</tr>
<tr>
<td>B 2</td>
<td>0.9500000E +02</td>
<td>0.5500000E +02</td>
</tr>
<tr>
<td>B 3</td>
<td>0.1350000E +03</td>
<td>0.9500000E +02</td>
</tr>
<tr>
<td>B 4</td>
<td>0.1300000E +03</td>
<td>0.5000000E +02</td>
</tr>
</tbody>
</table>

+++ LAYOUT AND EV +++

ALPHA = 0.00

<table>
<thead>
<tr>
<th>POSITION</th>
<th>DEPARTMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>I 1</td>
<td>B 1</td>
</tr>
<tr>
<td>I 2</td>
<td>B 4</td>
</tr>
<tr>
<td>I 3</td>
<td>B 2</td>
</tr>
<tr>
<td>I 4</td>
<td>B 3</td>
</tr>
</tbody>
</table>

EV = 0.1185000E +05