```
Problem(116) --> Data file name :    DD_01_Chandrasekharan(1987)_40x100.cfp

< Machines visited by parts: Process route numbers(PRN) >
=============================================================
Part[   1] = {   11,  13 }
Part[   2] = {   11,  13 }
Part[   3] = {   11,  13 }
Part[   4] = {   11,  13 }
Part[   5] = {   11,  13 }
Part[   6] = {   14,  35 }
Part[   7] = {   11,  13 }
Part[   8] = {    4,   9,  20 }
Part[   9] = {   24,  27,  29 }
Part[  10] = {    1,   7,  32 }
Part[  11] = {    4,   9,  20 }
Part[  12] = {   24,  27,  29 }
Part[  13] = {    4,   9,  20 }
Part[  14] = {    4,   9,  30 }
Part[  15] = {   14,  17,  35 }
Part[  16] = {   14,  17,  35 }
Part[  17] = {   24,  27,  29 }
Part[  18] = {    1,   3,   7 }
Part[  19] = {   24,  27,  29 }
Part[  20] = {    4,   9,  20 }
Part[  21] = {   11,  13,  17 }
Part[  22] = {    4,   9,  20 }
Part[  23] = {    4,   9,  20 }
Part[  24] = {   14,  17,  35 }
Part[  25] = {    7,  11,  13 }
Part[  26] = {   24,  27,  29 }
Part[  27] = {   11,  14,  35 }
Part[  28] = {   11,  13,  14 }
Part[  29] = {    1,   3,  32 }
Part[  30] = {   24,  27,  29 }
Part[  31] = {   24,  27,  29 }
Part[  32] = {    4,   9,  20 }
Part[  33] = {    1,   3,   7,  32 }
Part[  34] = {    1,   3,   7,  32 }
Part[  35] = {    2,  10,  16,  21 }
Part[  36] = {   12,  26,  38,  40 }
Part[  37] = {    1,   3,   7,  32 }
Part[  38] = {    6,  12,  26,  38 }
Part[  39] = {   14,  18,  34,  36 }
Part[  40] = {    8,  24,  27,  29 }
Part[  41] = {    3,   7,  27,  32 }
Part[  42] = {    6,  26,  38,  40 }
Part[  43] = {   11,  24,  27,  29 }
Part[  44] = {    1,   3,   7,  32 }
Part[  45] = {   15,  33,  34,  36 }
Part[  46] = {   24,  27,  28,  29 }
Part[  47] = {    2,  10,  16,  31 }
Part[  48] = {    3,  11,  13,  15 }
Part[  49] = {    1,   3,   7,  32 }
Part[  50] = {    1,   3,  12,  32 }
Part[  51] = {    6,  12,  26,  38 }
Part[  52] = {   12,  26,  38,  40 }
Part[  53] = {    2,  10,  21,  31 }
Part[  54] = {    1,   3,   7,  32 }
Part[  55] = {    1,   3,   7,  32 }
Part[  56] = {   19,  25,  28,  30 }
Part[  57] = {   19,  25,  28,  30 }
Part[  58] = {   19,  25,  28,  30 }
Part[  59] = {   19,  25,  28,  30 }
Part[  60] = {   13,  14,  17,  35 }
Part[  61] = {   19,  25,  28,  30 }
Part[  62] = {   19,  25,  28,  30 }
Part[  63] = {    5,   8,  37,  39 }
Part[  64] = {    6,  12,  26,  38,  40 }
Part[  65] = {    6,  16,  26,  38,  40 }
Part[  66] = {    5,   8,  22,  37,  39 }
Part[  67] = {   15,  18,  33,  34,  36 }
Part[  68] = {    5,   8,  22,  23,  37 }
Part[  69] = {    5,  22,  23,  37,  39 }
Part[  70] = {    6,  12,  26,  38,  40 }
Part[  71] = {   15,  18,  25,  33,  34 }
Part[  72] = {    6,  12,  21,  26,  40 }
Part[  73] = {   18,  19,  33,  34,  36 }
Part[  74] = {    6,  12,  26,  38,  40 }
Part[  75] = {    6,  12,  26,  40 }
Part[  76] = {    6,  12,  26,  36,  38,  40 }
Part[  77] = {   10,  16,  21,  23,  31 }
Part[  78] = {    2,  10,  16,  21,  40 }
Part[  79] = {    2,  10,  16,  21,  31 }
Part[  80] = {    6,  12,  26,  38,  40 }
Part[  81] = {    6,  12,  17,  28,  38,  40 }
Part[  82] = {    5,   8,  22,  23,  37,  39 }
Part[  83] = {    2,  10,  16,  21,  30,  31 }
Part[  84] = {    5,   8,   9,  22,  23,  37 }
```

```
Part[  85] = {    5,    8,   22,   23,   37,   39 }
Part[  86] = {    6,    8,   12,   16,   26,   38 }
Part[  87] = {    5,    6,   12,   26,   38,   40 }
Part[  88] = {    2,   10,   16,   21,   26,   31 }
Part[  89] = {    5,    8,   22,   23,   37,   39 }
Part[  90] = {    5,    8,   22,   23,   37,   39 }
Part[  91] = {   15,   18,   30,   33,   34,   36 }
Part[  92] = {    5,    8,   22,   23,   37,   39 }
Part[  93] = {    2,   10,   16,   21,   31,   36 }
Part[  94] = {    5,   22,   23,   36,   37,   39 }
Part[  95] = {    5,    8,   23,   37,   39,   40 }
Part[  96] = {    5,    8,   22,   23,   37,   39 }
Part[  97] = {    5,    8,   12,   22,   23,   37 }
Part[  98] = {    5,    8,   22,   23,   37,   39 }
Part[  99] = {    5,    8,   19,   22,   23,   37,   39 }
Part[ 100] = {    5,    8,   18,   22,   23,   37,   39 }
==============================================================

< Block Diagonal Solution Matrix >
                < Locations >
                0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
                0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2 2 3 3 3 3 3 3 3 3 3 3 4
                1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0
                < Machines >
                0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
                0 1 2 3 4 0 2 2 3 3 0 0 3 2 2 1 2 2 3 0 0 2 1 1 3 0 1 1 2 3 1 1 1 1 3 3 3
< Parts >       6 2 6 8 0 5 8 2 3 7 9 1 3 7 2 4 7 9 9 5 8 0 4 9 0 4 7 5 2 0 6 1 1 3 5 8 3 4 6
===========     * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
(    1)   36    *   1 1 1 1                                                                   *
(    2)   38    * 1 1 1 1                                                                     *
(    3)   42    * 1   1 1 1                                                                   *
(    4)   51    * 1 1 1 1                                                                     *
(    5)   52    *   1 1 1 1                                                                   *
(    6)   64    * 1 1 1 1 1                                                                   *
(    7)   65    * 1   1 1 1                                         1                         *
(    8)   70    * 1 1 1 1 1                                                                   *
(    9)   72    * 1 1 1   1                                           1                       *
(   10)   74    * 1 1 1 1 1                                                                   *
(   11)   75    * 1 1 1   1                                                                   *
(   12)   76    * 1 1 1 1 1                                                               1 *
(   13)   80    * 1 1 1 1 1                                                                   *
(   14)   81    * 1 1   1 1           1           1                   1                       *
(   15)   86    * 1 1 1 1   1                                         1                       *
(   16)   87    * 1 1 1 1 1 1                                                                 *
===========     * = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = *
(   17)   63    *         1 1     1 1                                                         *
(   18)   66    *         1 1 1   1 1                                                         *
(   19)   68    *         1 1 1 1 1                                                           *
(   20)   69    *         1   1 1 1 1                                                         *
(   21)   82    *         1 1 1 1 1 1                                                         *
(   22)   84    *         1 1 1 1 1             1                                             *
(   23)   85    *         1 1 1 1 1 1                                                         *
(   24)   89    *         1 1 1 1 1 1                                                         *
(   25)   90    *         1 1 1 1 1 1                                                         *
(   26)   92    *         1 1 1 1 1 1                                                         *
(   27)   94    *         1   1 1 1 1                                                     1 *
(   28)   95    *     1 1 1   1 1 1                                                         *
(   29)   96    *         1 1 1 1 1 1                                                         *
(   30)   97    *   1     1 1 1 1 1                                                           *
(   31)   98    *         1 1 1 1 1 1                                                         *
(   32)   99    *         1 1 1 1 1 1         1                                             *
(   33)  100    *         1 1 1 1 1 1                                             1           *
===========     * = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = *
(   34)   10    *                 1     1 1                                                   *
(   35)   18    *                 1 1 1                                                       *
(   36)   29    *                 1 1   1                                                     *
(   37)   33    *                 1 1 1 1                                                     *
(   38)   34    *                 1 1 1 1                                                     *
(   39)   37    *                 1 1 1 1                                                     *
(   40)   41    *                 1 1 1   1                                                   *
(   41)   44    *                 1 1 1 1                                                     *
(   42)   49    *                 1 1 1 1                                                     *
(   43)   50    *   1             1 1   1                                                     *
(   44)   54    *                 1 1 1 1                                                     *
(   45)   55    *                 1 1 1 1                                                     *
===========     * = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = *
(   46)    9    *                       1 1 1                                                 *
(   47)   12    *                       1 1 1                                                 *
(   48)   17    *                       1 1 1                                                 *
(   49)   19    *                       1 1 1                                                 *
(   50)   26    *                       1 1 1                                                 *
(   51)   30    *                       1 1 1                                                 *
(   52)   31    *                       1 1 1                                                 *
(   53)   40    *             1         1 1 1                                                 *
(   54)   43    *                       1 1 1                           1                     *
(   55)   46    *                       1 1 1     1                                           *
===========     * = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = *
(   56)   56    *                             1 1 1 1                                         *
```

```
(  57)   57  *                                     1 1 1 1                                                              *
(  58)   58  *                                     1 1 1 1                                                              *
(  59)   59  *                                     1 1 1 1                                                              *
(  60)   61  *                                     1 1 1 1                                                              *
(  61)   62  *                                     1 1 1 1                                                              *
===========  * = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = =  *
(  62)    8  *                                                 1 1 1                                                    *
(  63)   11  *                                                 1 1 1                                                    *
(  64)   13  *                                                 1 1 1                                                    *
(  65)   14  *                                             1 1 1                                                        *
(  66)   20  *                                                 1 1 1                                                    *
(  67)   22  *                                                 1 1 1                                                    *
(  68)   23  *                                                 1 1 1                                                    *
(  69)   32  *                                                 1 1 1                                                    *
===========  * = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = =  *
(  70)    6  *                                                     1   1                                                *
(  71)   15  *                                                     1 1 1                                                *
(  72)   16  *                                                     1 1 1                                                *
(  73)   24  *                                                     1 1 1                                                *
(  74)   27  *                                                     1   1               1                                *
(  75)   60  *                                                     1 1 1                 1                              *
===========  * = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = =  *
(  76)   35  *                                                             1 1 1 1                                      *
(  77)   47  *                                                             1 1 1   1                                    *
(  78)   53  *                                                             1 1   1 1                                    *
(  79)   77  *                         1           1                       1 1 1 1                                      *
(  80)   78  *               1                                             1 1 1 1                                      *
(  81)   79  *                                                             1 1 1 1 1                                    *
(  82)   83  *                                         1                   1 1 1 1 1                                    *
(  83)   88  *           1                                                 1 1 1 1 1                                    *
(  84)   93  *                                                             1 1 1 1 1                       1            *
===========  * = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = =  *
(  85)    1  *                                                                     1 1                                  *
(  86)    2  *                                                                     1 1                                  *
(  87)    3  *                                                                     1 1                                  *
(  88)    4  *                                                                     1 1                                  *
(  89)    5  *                                                                     1 1                                  *
(  90)    7  *                                                                     1 1                                  *
(  91)   21  *                                                         1           1 1                                  *
(  92)   25  *                                 1                                   1 1                                  *
(  93)   28  *                                                     1               1 1                                  *
(  94)   48  *                               1                                     1 1 1                                *
===========  * = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = =  *
(  95)   39  *                                                         1                       1     1 1               *
(  96)   45  *                                                                             1   1 1 1 1               *
(  97)   67  *                                                                             1 1 1 1 1               *
(  98)   71  *                                   1                                         1 1 1 1                 *
(  99)   73  *                               1                                             1 1 1 1 1               *
( 100)   91  *                                     1                                       1 1 1 1 1 *
===========  * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *  *
```

< Machine cells and Part families >
```
=========================================================
Machine Cell[ 1] = { 6, 12, 26, 38, 40 }
Machine Cell[ 2] = { 5, 8, 22, 23, 37, 39 }
Machine Cell[ 3] = { 1, 3, 7, 32 }
Machine Cell[ 4] = { 24, 27, 29 }
Machine Cell[ 5] = { 19, 25, 28, 30 }
Machine Cell[ 6] = { 4, 9, 20 }
Machine Cell[ 7] = { 14, 17, 35 }
Machine Cell[ 8] = { 2, 10, 16, 21, 31 }
Machine Cell[ 9] = { 11, 13 }
Machine Cell[10] = { 15, 18, 33, 34, 36 }
=========================================================
Part  Family[ 1] = { 36, 38, 42, 51, 52, 64, 65, 70, 72, 74, 75, 76, 80, 81, 86, 87 }
Part  Family[ 2] = { 63, 66, 68, 69, 82, 84, 85, 89, 90, 92, 94, 95, 96, 97, 98, 99, 100 }
Part  Family[ 3] = { 10, 18, 29, 33, 34, 37, 41, 44, 49, 50, 54, 55 }
Part  Family[ 4] = { 9, 12, 17, 19, 26, 30, 31, 40, 43, 46 }
Part  Family[ 5] = { 56, 57, 58, 59, 61, 62 }
Part  Family[ 6] = { 8, 11, 13, 14, 20, 22, 23, 32 }
Part  Family[ 7] = { 6, 15, 16, 24, 27, 60 }
Part  Family[ 8] = { 35, 47, 53, 77, 78, 79, 83, 88, 93 }
Part  Family[ 9] = { 1, 2, 3, 4, 5, 7, 21, 25, 28, 48 }
Part  Family[10] = { 39, 45, 67, 71, 73, 91 }
=========================================================
```

< Summary of the performance measures >
```
=========================================================
No. of machines                            = 40
No. of part types                          = 100
No. of cells                               = 10
Machine cell size                          = 6
Total no. of 1's in the original MPIM : |A| = 420
Matrix density                             = 0.105
Total no. of within-block 1's              = 384
No. of exceptional elements (EEs)          = 36
No. of voids                               = 37
Sum of EEs and voids                       = 73
```

```
Group Cability Index (GCI)              = 91.43 %
grouping efficiency (GE)                = 95.10 %
Grouping efficacy (GF)                  = 84.03 %
Machine utilization (MU)                = 91.21 %
No. of redundant machines (RMs)         = 0
============================================================
```

```
Problem(117) --> Data file name :    DD_02_Gindy(1996)_45x120.cfp

< Machines visited by parts: Process route numbers(PRN) >
================================================================
Part[   1] = {    5 }
Part[   2] = {    9,   40,   14 }
Part[   3] = {    9,   23 }
Part[   4] = {   13,   34 }
Part[   5] = {   13 }
Part[   6] = {   13,   27 }
Part[   7] = {   13,   26 }
Part[   8] = {    6,   11,   14 }
Part[   9] = {   30,   33 }
Part[  10] = {    4,   15 }
Part[  11] = {   22,   29,   31,   45 }
Part[  12] = {    4,    8 }
Part[  13] = {    4 }
Part[  14] = {   12 }
Part[  15] = {    3 }
Part[  16] = {    2,   27 }
Part[  17] = {    2,   13 }
Part[  18] = {    2 }
Part[  19] = {    2,   13,   27 }
Part[  20] = {    3,   19 }
Part[  21] = {   33 }
Part[  22] = {   15,   32 }
Part[  23] = {    7,   16 }
Part[  24] = {   21,   40 }
Part[  25] = {    5,    7 }
Part[  26] = {    6,    7,   23 }
Part[  27] = {    6,   23,   43 }
Part[  28] = {   41,   12,   44 }
Part[  29] = {   26 }
Part[  30] = {   25,   26 }
Part[  31] = {    4,   32 }
Part[  32] = {    4,   32,   45 }
Part[  33] = {   39,   45 }
Part[  34] = {   20 }
Part[  35] = {    7,    6,   16 }
Part[  36] = {    8,   19 }
Part[  37] = {    9,   21,   16 }
Part[  38] = {   17 }
Part[  39] = {   17,   26 }
Part[  40] = {   26,   30 }
Part[  41] = {   27,   33 }
Part[  42] = {   27 }
Part[  43] = {   15,   32,   45 }
Part[  44] = {   17,   33 }
Part[  45] = {   26,   27 }
Part[  46] = {   17,   27 }
Part[  47] = {   25,   27 }
Part[  48] = {   26,   27,   33 }
Part[  49] = {   17,   20,   27 }
Part[  50] = {   20,   27 }
Part[  51] = {    5,   41 }
Part[  52] = {   25,   26,   30 }
Part[  53] = {    5,   12 }
Part[  54] = {    8 }
Part[  55] = {    8,   15 }
Part[  56] = {   32,   45 }
Part[  57] = {   16,   42 }
Part[  58] = {   17,   20,   33 }
Part[  59] = {   34 }
Part[  60] = {   42 }
```

```
Part[  61] = {   35 }
Part[  62] = {   38 }
Part[  63] = {   36 }
Part[  64] = {   11 }
Part[  65] = {   25 }
Part[  66] = {    5,   40 }
Part[  67] = {    9,   41 }
Part[  68] = {   17,   25,   27 }
Part[  69] = {   27,   30 }
Part[  70] = {   16,   21 }
Part[  71] = {    9,   40 }
Part[  72] = {    9,   21,   16 }
Part[  73] = {   10 }
Part[  74] = {   28 }
Part[  75] = {   38,   40 }
Part[  76] = {   40 }
Part[  77] = {   41 }
Part[  78] = {   41,   43 }
Part[  79] = {    8,   15,   38 }
Part[  80] = {   28,   40 }
Part[  81] = {    8,   15,   29 }
Part[  82] = {   40,   41 }
Part[  83] = {    9,   43 }
Part[  84] = {    8,   15,   31 }
Part[  85] = {   30,   40,   41 }
Part[  86] = {    8,   15,   32 }
Part[  87] = {   28,   38,   40 }
Part[  88] = {   17,   25 }
Part[  89] = {    6,   16,   37 }
Part[  90] = {    1,    7,   16 }
Part[  91] = {    1,   16 }
Part[  92] = {    4,    8,   31 }
Part[  93] = {    4,   31 }
Part[  94] = {   39 }
Part[  95] = {   17,   18,   25 }
Part[  96] = {    3,   15,   32 }
Part[  97] = {   28,   36,   40 }
Part[  98] = {    9 }
Part[  99] = {    1,    6,   24 }
Part[ 100] = {    6,   16 }
Part[ 101] = {    1,    6,   14 }
Part[ 102] = {    1,    6,   23 }
Part[ 103] = {    1,    6,    7 }
Part[ 104] = {    1,   16,   43 }
Part[ 105] = {    6,   16,   35,   43 }
Part[ 106] = {   20,   26 }
Part[ 107] = {   17,   20,   26 }
Part[ 108] = {   17,   18,   33 }
Part[ 109] = {   32 }
Part[ 110] = {    7,   37 }
Part[ 111] = {    7,   43 }
Part[ 112] = {   34,   35 }
Part[ 113] = {    9,   16,   23 }
Part[ 114] = {    9,   16 }
Part[ 115] = {   16 }
Part[ 116] = {    4,   12 }
Part[ 117] = {    4,   29 }
Part[ 118] = {   14 }
Part[ 119] = {    1,    6,   16,   43 }
Part[ 120] = {   37 }
================================================================
```

< Block Diagonal Solution Matrix >
             < Locations >

```
                   0000000000000000000000000000000000000000000000
                   0000000000111111111122222222223333333333444444
                   1234567890123456789012345678901234567890012345
                   < Machines >
                   0000000000000000000000000000000000000000000000
                   0000112234011122223301223344400112233340111 33
 < Parts >         1679461373237805670352486801244805291295319 45
===========        **********************************************
(     1)    2      *   11                        1              *
(     2)    3      *   1    1                                   *
(     3)    8      * 1  1                                     1 *
(     4)   23      *  1   1                                     *
(     5)   26      * 11     1                                   *
(     6)   27      * 1       1 1                                *
(     7)   35      * 11    1                                    *
(     8)   37      *   1 11                                     *
(     9)   57      *     1              1                       *
(    10)   70      *     11                                     *
(    11)   72      *   1 11                                     *
(    12)   78      *        1            1                      *
(    13)   83      *   1       1                                *
(    14)   89      * 1    1   1                                 *
(    15)   90      *1 1   1                                     *
(    16)   91      *1      1                                    *
(    17)   98      *    1                                       *
(    18)   99      *11              1                           *
(    19)  100      * 1    1                                     *
(    20)  101      *11   1                                      *
(    21)  102      *11       1                                  *
(    22)  103      *111                                         *
(    23)  104      *1      1     1                              *
(    24)  105      *  1     1     1                          1*
(    25)  110      *   1       1                                *
(    26)  111      *   1        1                               *
(    27)  113      *    1 1 1                                   *
(    28)  114      *    1 1                                     *
(    29)  115      *     1                                      *
(    30)  118      *      1                                     *
(    31)  119      *11     1    1                               *
(    32)  120      *            1                               *
===========        *==========================================*
(    33)    4      *              1                          1 *
(    34)    5      *              1                            *
(    35)    6      *              1      1                     *
(    36)    7      *              1      1                     *
(    37)    9      *                   11                      *
(    38)   16      *           1       1                       *
(    39)   17      *          11                               *
(    40)   18      *          1                                *
(    41)   19      *          11      1                        *
(    42)   21      *                 1                         *
(    43)   29      *             1                             *
(    44)   30      *             11                            *
(    45)   34      *           1                               *
(    46)   38      *         1                                 *
(    47)   39      *         1    1                            *
(    48)   40      *            1 1                             *
(    49)   41      *             1 1                           *
(    50)   42      *             1                             *
(    51)   44      *         1       1                         *
(    52)   45      *            11                             *
(    53)   46      *         1    1                            *
(    54)   47      *            1 1                            *
(    55)   48      *            11 1                           *
```

```
(  56)   49   *            1 1   1                                    *
(  57)   50   *            1 1                                        *
(  58)   52   *             11 1                                      *
(  59)   58   *            1 1     1                                  *
(  60)   65   *               1                                      *
(  61)   68   *            1   1 1                                    *
(  62)   69   *                 11                                    *
(  63)   88   *            1   1                                      *
(  64)   95   *            11  1                                      *
(  65)  106   *             1 1                                       *
(  66)  107   *            1 1 1                                      *
(  67)  108   *            11       1                                *
==========   *=================================================*
(  68)    1   *                         1                           *
(  69)   14   *                          1                          *
(  70)   24   *        1                       1                    *
(  71)   25   *    1                    1                           *
(  72)   28   *                         1     1 1                   *
(  73)   51   *                         1     1                     *
(  74)   53   *                         11                          *
(  75)   60   *                             1                       *
(  76)   62   *                        1                            *
(  77)   63   *                       1                             *
(  78)   66   *                     1     1                         *
(  79)   67   *      1                     1                        *
(  80)   71   *      1                     1                        *
(  81)   74   *                    1                                *
(  82)   75   *                     11                              *
(  83)   76   *                      1                              *
(  84)   77   *                      1                              *
(  85)   80   *                   1   1                             *
(  86)   82   *                     11                              *
(  87)   85   *             1         11                            *
(  88)   87   *                   1 11                              *
(  89)   97   *                  11 1                               *
==========   *=================================================*
(  90)   10   *                           1   1                     *
(  91)   11   *                            111   1                  *
(  92)   12   *                          11                         *
(  93)   13   *                          1                          *
(  94)   22   *                            1     1                  *
(  95)   31   *                          1       1                  *
(  96)   32   *                          1         1 1              *
(  97)   33   *                              11                     *
(  98)   43   *                           1     1 1                 *
(  99)   54   *                         1                           *
( 100)   55   *                          1 1                        *
( 101)   56   *                              1 1                    *
( 102)   73   *                          1                          *
( 103)   79   *                  1       1 1                        *
( 104)   81   *                          1 1 1                      *
( 105)   84   *                          1 1   1                    *
( 106)   86   *                          1 1   1                    *
( 107)   92   *                          11     1                   *
( 108)   93   *                          1       1                  *
( 109)   94   *                                1                    *
( 110)   96   *                            1   1 1                  *
( 111)  109   *                                1                    *
( 112)  116   *                  1       1                          *
( 113)  117   *                          1     1                    *
==========   *=================================================*
( 114)   15   *                                    1                *
( 115)   20   *                                    1 1              *
( 116)   36   *                         1             1             *
```

```
( 117)  59  *                                                             1 *
( 118)  61  *                                                               1*
( 119)  64  *                                                           1   *
( 120) 112  *                                                              11*
==========  *******************************************************
```

< Machine cells and Part families >
```
=================================================================
Machine Cell[ 1] = { 1, 6, 7, 9, 14, 16, 21, 23, 37, 43 }
Machine Cell[ 2] = { 2, 13, 17, 18, 20, 25, 26, 27, 30, 33 }
Machine Cell[ 3] = { 5, 12, 24, 28, 36, 38, 40, 41, 42, 44 }
Machine Cell[ 4] = { 4, 8, 10, 15, 22, 29, 31, 32, 39, 45 }
Machine Cell[ 5] = { 3, 11, 19, 34, 35 }
=================================================================
Part  Family[ 1] = { 2, 3, 8, 23, 26, 27, 35, 37, 57, 70, 72, 78, 83, 89,
90, 91, 98, 99, 100, 101, 102, 103, 104, 105, 110, 111, 113, 114, 115,
118, 119, 120 }
Part  Family[ 2] = { 4, 5, 6, 7, 9, 16, 17, 18, 19, 21, 29, 30, 34, 38,
39, 40, 41, 42, 44, 45, 46, 47, 48, 49, 50, 52, 58, 65, 68, 69, 88, 95,
106, 107, 108 }
Part  Family[ 3] = { 1, 14, 24, 25, 28, 51, 53, 60, 62, 63, 66, 67, 71,
74, 75, 76, 77, 80, 82, 85, 87, 97 }
Part  Family[ 4] = { 10, 11, 12, 13, 22, 31, 32, 33, 43, 54, 55, 56, 73,
79, 81, 84, 86, 92, 93, 94, 96, 109, 116, 117 }
Part  Family[ 5] = { 15, 20, 36, 59, 61, 64, 112 }
=================================================================
```

< Summary of the performance measures >
```
=================================================================
No. of machines                          = 45
No. of part types                        = 120
No. of cells                             = 5
Machine cell size                        = 10
Total no. of 1's in the original MPIM : |A| = 253
Matrix density                           = 0.0469
Total no. of within-block 1's            = 237
No. of exceptional elements (EEs)        = 16
No. of voids                             = 928
Sum of EEs and voids                     = 944
Group Cability Index (GCI)               = 93.68 %
grouping efficiency (GE)                 = 59.98 %
Grouping efficacy (GF)                   = 20.07 %
Machine utilization (MU)                 = 20.34 %
No. of redundant machines (RMs)          = 1
=================================================================
```

```
Problem(117) --> Data file name :    DD_02_Gindy(1996)_45x120.cfp

< Machines visited by parts: Process route numbers(PRN) >
================================================================
Part[   1] = {    5 }
Part[   2] = {    9,   40,   14 }
Part[   3] = {    9,   23 }
Part[   4] = {   13,   34 }
Part[   5] = {   13 }
Part[   6] = {   13,   27 }
Part[   7] = {   13,   26 }
Part[   8] = {    6,   11,   14 }
Part[   9] = {   30,   33 }
Part[  10] = {    4,   15 }
Part[  11] = {   22,   29,   31,   45 }
Part[  12] = {    4,    8 }
Part[  13] = {    4 }
Part[  14] = {   12 }
Part[  15] = {    3 }
Part[  16] = {    2,   27 }
Part[  17] = {    2,   13 }
Part[  18] = {    2 }
Part[  19] = {    2,   13,   27 }
Part[  20] = {    3,   19 }
Part[  21] = {   33 }
Part[  22] = {   15,   32 }
Part[  23] = {    7,   16 }
Part[  24] = {   21,   40 }
Part[  25] = {    5,    7 }
Part[  26] = {    6,    7,   23 }
Part[  27] = {    6,   23,   43 }
Part[  28] = {   41,   12,   44 }
Part[  29] = {   26 }
Part[  30] = {   25,   26 }
Part[  31] = {    4,   32 }
Part[  32] = {    4,   32,   45 }
Part[  33] = {   39,   45 }
Part[  34] = {   20 }
Part[  35] = {    7,    6,   16 }
Part[  36] = {    8,   19 }
Part[  37] = {    9,   21,   16 }
Part[  38] = {   17 }
Part[  39] = {   17,   26 }
Part[  40] = {   26,   30 }
Part[  41] = {   27,   33 }
Part[  42] = {   27 }
Part[  43] = {   15,   32,   45 }
Part[  44] = {   17,   33 }
Part[  45] = {   26,   27 }
Part[  46] = {   17,   27 }
Part[  47] = {   25,   27 }
Part[  48] = {   26,   27,   33 }
Part[  49] = {   17,   20,   27 }
Part[  50] = {   20,   27 }
Part[  51] = {    5,   41 }
Part[  52] = {   25,   26,   30 }
Part[  53] = {    5,   12 }
Part[  54] = {    8 }
Part[  55] = {    8,   15 }
Part[  56] = {   32,   45 }
Part[  57] = {   16,   42 }
Part[  58] = {   17,   20,   33 }
Part[  59] = {   34 }
Part[  60] = {   42 }
```

```
Part[  61] = {   35 }
Part[  62] = {   38 }
Part[  63] = {   36 }
Part[  64] = {   11 }
Part[  65] = {   25 }
Part[  66] = {    5,   40 }
Part[  67] = {    9,   41 }
Part[  68] = {   17,   25,   27 }
Part[  69] = {   27,   30 }
Part[  70] = {   16,   21 }
Part[  71] = {    9,   40 }
Part[  72] = {    9,   21,   16 }
Part[  73] = {   10 }
Part[  74] = {   28 }
Part[  75] = {   38,   40 }
Part[  76] = {   40 }
Part[  77] = {   41 }
Part[  78] = {   41,   43 }
Part[  79] = {    8,   15,   38 }
Part[  80] = {   28,   40 }
Part[  81] = {    8,   15,   29 }
Part[  82] = {   40,   41 }
Part[  83] = {    9,   43 }
Part[  84] = {    8,   15,   31 }
Part[  85] = {   30,   40,   41 }
Part[  86] = {    8,   15,   32 }
Part[  87] = {   28,   38,   40 }
Part[  88] = {   17,   25 }
Part[  89] = {    6,   16,   37 }
Part[  90] = {    1,    7,   16 }
Part[  91] = {    1,   16 }
Part[  92] = {    4,    8,   31 }
Part[  93] = {    4,   31 }
Part[  94] = {   39 }
Part[  95] = {   17,   18,   25 }
Part[  96] = {    3,   15,   32 }
Part[  97] = {   28,   36,   40 }
Part[  98] = {    9 }
Part[  99] = {    1,    6,   24 }
Part[ 100] = {    6,   16 }
Part[ 101] = {    1,    6,   14 }
Part[ 102] = {    1,    6,   23 }
Part[ 103] = {    1,    6,    7 }
Part[ 104] = {    1,   16,   43 }
Part[ 105] = {    6,   16,   35,   43 }
Part[ 106] = {   20,   26 }
Part[ 107] = {   17,   20,   26 }
Part[ 108] = {   17,   18,   33 }
Part[ 109] = {   32 }
Part[ 110] = {    7,   37 }
Part[ 111] = {    7,   43 }
Part[ 112] = {   34,   35 }
Part[ 113] = {    9,   16,   23 }
Part[ 114] = {    9,   16 }
Part[ 115] = {   16 }
Part[ 116] = {    4,   12 }
Part[ 117] = {    4,   29 }
Part[ 118] = {   14 }
Part[ 119] = {    1,    6,   16,   43 }
Part[ 120] = {   37 }
==============================================================
```

< Block Diagonal Solution Matrix >
            < Locations >

```
                    000000000000000000000000000000000000000000000
                    000000000011111111112222222222333333333444444
                    123456789012345678901234567890123456789012345
                    < Machines >
                    000000000000000000000000000000000000000000000
                    000012234011222233011233444001223334011141233
  < Parts >         167961373237056703524868014485291295301928445
  ===========       *********************************************
  (    1)      3    *    1  1                                      *
  (    2)     23    *    1 1                                       *
  (    3)     25    *    1               1                         *
  (    4)     26    * 11    1                                      *
  (    5)     27    * 1       1 1                                  *
  (    6)     35    * 11 1                                         *
  (    7)     37    *    111                                       *
  (    8)     57    *     1                              1         *
  (    9)     67    *     1                    1                   *
  (   10)     70    *     11                                       *
  (   11)     72    *     111                                      *
  (   12)     83    *    1     1                                   *
  (   13)     89    * 1   1    1                                   *
  (   14)     90    *1 1  1                                        *
  (   15)     91    *1    1                                        *
  (   16)     98    *     1                                        *
  (   17)     99    *11                                    1       *
  (   18)    100    *  1   1                                       *
  (   19)    101    *11              1                             *
  (   20)    102    *11      1                                     *
  (   21)    103    *111                                           *
  (   22)    104    *1     1     1                                 *
  (   23)    105    *  1   1     1                               1*
  (   24)    110    *   1      1                                   *
  (   25)    111    *   1        1                                 *
  (   26)    113    *     11 1                                     *
  (   27)    114    *     11                                       *
  (   28)    115    *      1                                       *
  (   29)    119    *11    1     1                                 *
  (   30)    120    *          1                                   *
  ===========       *=========================================*
  (   31)      5    *             1                                *
  (   32)      6    *             1     1                          *
  (   33)      7    *             1    1                           *
  (   34)      9    *               11                             *
  (   35)     16    *          1      1                            *
  (   36)     17    *          11                                  *
  (   37)     18    *          1                                   *
  (   38)     19    *          11     1                            *
  (   39)     21    *                1                             *
  (   40)     29    *             1                                *
  (   41)     30    *            11                                *
  (   42)     34    *           1                                  *
  (   43)     38    *          1                                   *
  (   44)     39    *          1  1                                *
  (   45)     40    *            1 1                               *
  (   46)     41    *             1 1                              *
  (   47)     42    *             1                                *
  (   48)     44    *          1     1                             *
  (   49)     45    *            11                                *
  (   50)     46    *          1   1                               *
  (   51)     47    *            1 1                               *
  (   52)     48    *             11 1                             *
  (   53)     49    *         11   1                               *
  (   54)     50    *          1  1                                *
  (   55)     52    *            11 1                              *
```

```
(  56)  58 *          11     1                              *
(  57)  65 *            1                                   *
(  58)  68 *          1 1 1                                 *
(  59)  69 *              11                                *
(  60)  88 *          1 1                                   *
(  61)  95 *          1 1                           1       *
(  62) 106 *           1 1                                  *
(  63) 107 *          11 1                                  *
(  64) 108 *          1        1                     1      *
========== *=================================================*
(  65)   1 *                      1                         *
(  66)   2 *     1              1   1                        *
(  67)   8 * 1                  1                 1          *
(  68)  14 *                    1                           *
(  69)  24 *       1               1                        *
(  70)  28 *                  1      11                     *
(  71)  51 *                  1       1                     *
(  72)  53 *                  11                            *
(  73)  62 *                    1                           *
(  74)  63 *                   1                            *
(  75)  66 *                  1     1                       *
(  76)  71 *     1                  1                       *
(  77)  74 *                   1                            *
(  78)  75 *                     11                         *
(  79)  76 *                     1                          *
(  80)  77 *                      1                         *
(  81)  78 *          1           1                         *
(  82)  80 *                  1  1                          *
(  83)  82 *                     11                         *
(  84)  85 *             1       11                         *
(  85)  87 *                  1 11                          *
(  86)  97 *                 11 1                           *
(  87) 118 *                 1                              *
========== *=================================================*
(  88)  10 *                        1 1                     *
(  89)  11 *                         111   1                *
(  90)  12 *                       11                       *
(  91)  13 *                       1                        *
(  92)  22 *                        1     1                 *
(  93)  31 *                       1     1                  *
(  94)  32 *                       1       1 1              *
(  95)  33 *                             11                 *
(  96)  43 *                       1     1 1                *
(  97)  54 *                       1                        *
(  98)  55 *                       11                       *
(  99)  56 *                          1 1                   *
( 100)  79 *                 1       11                     *
( 101)  81 *                        11 1                    *
( 102)  84 *                        11  1                   *
( 103)  86 *                        11    1                 *
( 104)  92 *                       11    1                  *
( 105)  93 *                       1     1                  *
( 106)  94 *                          1                     *
( 107)  96 *                     1     1  1                 *
( 108) 109 *                          1                     *
( 109) 116 *              1        1                        *
( 110) 117 *                       1    1                   *
========== *=================================================*
( 111)  15 *                            1                   *
( 112)  20 *                            1  1                *
( 113)  36 *                   1         1                  *
( 114)  60 *                             1                  *
( 115)  64 *                           1                    *
( 116)  73 *                          1                     *
```

```
==========  *==============================================*
( 117)    4  *              1                              1 *
( 118)   59  *                                             1 *
( 119)   61  *                                              1*
( 120)  112  *                                             11*
==========  ********************************************
```

< Machine cells and Part families >
```
==============================================================
Machine Cell[ 1] = { 1, 6, 7, 9, 16, 21, 23, 37, 43 }
Machine Cell[ 2] = { 2, 13, 17, 20, 25, 26, 27, 30, 33 }
Machine Cell[ 3] = { 5, 12, 14, 28, 36, 38, 40, 41, 44 }
Machine Cell[ 4] = { 4, 8, 15, 22, 29, 31, 32, 39, 45 }
Machine Cell[ 5] = { 3, 10, 11, 19, 42 }
Machine Cell[ 6] = { 18, 24, 34, 35 }
==============================================================
Part  Family[ 1] = { 3, 23, 25, 26, 27, 35, 37, 57, 67, 70, 72, 83, 89,
90, 91, 98, 99, 100, 101, 102, 103, 104, 105, 110, 111, 113, 114, 115,
119, 120 }
Part  Family[ 2] = { 5, 6, 7, 9, 16, 17, 18, 19, 21, 29, 30, 34, 38, 39,
40, 41, 42, 44, 45, 46, 47, 48, 49, 50, 52, 58, 65, 68, 69, 88, 95, 106,
107, 108 }
Part  Family[ 3] = { 1, 2, 8, 14, 24, 28, 51, 53, 62, 63, 66, 71, 74, 75,
76, 77, 78, 80, 82, 85, 87, 97, 118 }
Part  Family[ 4] = { 10, 11, 12, 13, 22, 31, 32, 33, 43, 54, 55, 56, 79,
81, 84, 86, 92, 93, 94, 96, 109, 116, 117 }
Part  Family[ 5] = { 15, 20, 36, 60, 64, 73 }
Part  Family[ 6] = { 4, 59, 61, 112 }
==============================================================
```

< Summary of the performance measures >
```
==============================================================
No. of machines                         = 45
No. of part types                       = 120
No. of cells                            = 6
Machine cell size                       = 9
Total no. of 1's in the original MPIM : |A| = 253
Matrix density                          = 0.0469
Total no. of within-block 1's           = 233
No. of exceptional elements (EEs)       = 20
No. of voids                            = 803
Sum of EEs and voids                    = 823
Group Cability Index (GCI)              = 92.09 %
grouping efficiency (GE)                = 61.02 %
Grouping efficacy (GF)                  = 22.06 %
Machine utilization (MU)                = 22.49 %
No. of redundant machines (RMs)         = 2
==============================================================
```

< Machines visited by parts: Process route numbers(PRN) >
==
```
Part[   1] = {    5 }
Part[   2] = {    9,   40,   14 }
Part[   3] = {    9,   23 }
Part[   4] = {   13,   34 }
Part[   5] = {   13 }
Part[   6] = {   13,   27 }
Part[   7] = {   13,   26 }
Part[   8] = {    6,   11,   14 }
Part[   9] = {   30,   33 }
Part[  10] = {    4,   15 }
Part[  11] = {   22,   29,   31,   45 }
Part[  12] = {    4,    8 }
Part[  13] = {    4 }
Part[  14] = {   12 }
Part[  15] = {    3 }
Part[  16] = {    2,   27 }
Part[  17] = {    2,   13 }
Part[  18] = {    2 }
Part[  19] = {    2,   13,   27 }
Part[  20] = {    3,   19 }
Part[  21] = {   33 }
Part[  22] = {   15,   32 }
Part[  23] = {    7,   16 }
Part[  24] = {   21,   40 }
Part[  25] = {    5,    7 }
Part[  26] = {    6,    7,   23 }
Part[  27] = {    6,   23,   43 }
Part[  28] = {   41,   12,   44 }
Part[  29] = {   26 }
Part[  30] = {   25,   26 }
Part[  31] = {    4,   32 }
Part[  32] = {    4,   32,   45 }
Part[  33] = {   39,   45 }
Part[  34] = {   20 }
Part[  35] = {    7,    6,   16 }
Part[  36] = {    8,   19 }
Part[  37] = {    9,   21,   16 }
Part[  38] = {   17 }
Part[  39] = {   17,   26 }
Part[  40] = {   26,   30 }
Part[  41] = {   27,   33 }
Part[  42] = {   27 }
Part[  43] = {   15,   32,   45 }
Part[  44] = {   17,   33 }
Part[  45] = {   26,   27 }
Part[  46] = {   17,   27 }
Part[  47] = {   25,   27 }
Part[  48] = {   26,   27,   33 }
Part[  49] = {   17,   20,   27 }
Part[  50] = {   20,   27 }
Part[  51] = {    5,   41 }
Part[  52] = {   25,   26,   30 }
Part[  53] = {    5,   12 }
Part[  54] = {    8 }
Part[  55] = {    8,   15 }
Part[  56] = {   32,   45 }
Part[  57] = {   16,   42 }
Part[  58] = {   17,   20,   33 }
Part[  59] = {   34 }
Part[  60] = {   42 }
```

```
Part[  61] = {   35 }
Part[  62] = {   38 }
Part[  63] = {   36 }
Part[  64] = {   11 }
Part[  65] = {   25 }
Part[  66] = {    5,   40 }
Part[  67] = {    9,   41 }
Part[  68] = {   17,   25,   27 }
Part[  69] = {   27,   30 }
Part[  70] = {   16,   21 }
Part[  71] = {    9,   40 }
Part[  72] = {    9,   21,   16 }
Part[  73] = {   10 }
Part[  74] = {   28 }
Part[  75] = {   38,   40 }
Part[  76] = {   40 }
Part[  77] = {   41 }
Part[  78] = {   41,   43 }
Part[  79] = {    8,   15,   38 }
Part[  80] = {   28,   40 }
Part[  81] = {    8,   15,   29 }
Part[  82] = {   40,   41 }
Part[  83] = {    9,   43 }
Part[  84] = {    8,   15,   31 }
Part[  85] = {   30,   40,   41 }
Part[  86] = {    8,   15,   32 }
Part[  87] = {   28,   38,   40 }
Part[  88] = {   17,   25 }
Part[  89] = {    6,   16,   37 }
Part[  90] = {    1,    7,   16 }
Part[  91] = {    1,   16 }
Part[  92] = {    4,    8,   31 }
Part[  93] = {    4,   31 }
Part[  94] = {   39 }
Part[  95] = {   17,   18,   25 }
Part[  96] = {    3,   15,   32 }
Part[  97] = {   28,   36,   40 }
Part[  98] = {    9 }
Part[  99] = {    1,    6,   24 }
Part[ 100] = {    6,   16 }
Part[ 101] = {    1,    6,   14 }
Part[ 102] = {    1,    6,   23 }
Part[ 103] = {    1,    6,    7 }
Part[ 104] = {    1,   16,   43 }
Part[ 105] = {    6,   16,   35,   43 }
Part[ 106] = {   20,   26 }
Part[ 107] = {   17,   20,   26 }
Part[ 108] = {   17,   18,   33 }
Part[ 109] = {   32 }
Part[ 110] = {    7,   37 }
Part[ 111] = {    7,   43 }
Part[ 112] = {   34,   35 }
Part[ 113] = {    9,   16,   23 }
Part[ 114] = {    9,   16 }
Part[ 115] = {   16 }
Part[ 116] = {    4,   12 }
Part[ 117] = {    4,   29 }
Part[ 118] = {   14 }
Part[ 119] = {    1,    6,   16,   43 }
Part[ 120] = {   37 }
================================================================

              < Block Diagonal Solution Matrix >
                      < Locations >
```

```
                    0000000000000000000000000000000000000000000000
                    0000000000111111111122222222223333333333444444
                    1234567890123456789012345678901234567890123456
                    < Machines >
                    0000000000000000000000000000000000000000000000
                    0000122411222233012334400123334010113334 1122
< Parts >           1679613378056703528680144859129539203457 21424
===========         **********************************************
(     1)     3      *    1  1                                     *
(     2)    23      *   1 1                                       *
(     3)    25      *   1              1                          *
(     4)    26      * 11    1                                     *
(     5)    27      * 1      11                                   *
(     6)    35      * 11 1                                        *
(     7)    37      *    111                                      *
(     8)    57      *     1                               1       *
(     9)    67      *     1                  1                    *
(    10)    70      *      11                                     *
(    11)    72      *     111                                     *
(    12)    78      *        1            1                       *
(    13)    83      *    1    1                                   *
(    14)    89      * 1   1                            1          *
(    15)    90      *1 1  1                                       *
(    16)    91      *1     1                                      *
(    17)    98      *      1                                      *
(    18)    99      *11                                          1*
(    19)   100      *  1   1                                      *
(    20)   101      *11                                     1     *
(    21)   102      *11      1                                    *
(    22)   103      *111                                          *
(    23)   104      *1    1    1                                  *
(    24)   105      *  1   1   1                         1        *
(    25)   111      *     1      1                                *
(    26)   113      *     11  1                                   *
(    27)   114      *     11                                      *
(    28)   115      *      1                                      *
(    29)   119      *11    1   1                                  *
===========         *========================================*
(    30)     6      *              1                     1        *
(    31)     9      *                11                           *
(    32)    16      *              1                  1           *
(    33)    21      *                  1                          *
(    34)    29      *            1                                *
(    35)    30      *             11                              *
(    36)    34      *            1                                *
(    37)    38      *         1                                   *
(    38)    39      *          1     1                            *
(    39)    40      *              1 1                            *
(    40)    41      *               1 1                           *
(    41)    42      *               1                             *
(    42)    44      *         1         1                         *
(    43)    45      *             11                              *
(    44)    46      *         1       1                           *
(    45)    47      *            1 1                              *
(    46)    48      *            11 1                             *
(    47)    49      *        1 1   1                              *
(    48)    50      *          1   1                              *
(    49)    52      *            11 1                             *
(    50)    58      *        1 1      1                           *
(    51)    65      *             1                               *
(    52)    68      *        1   1 1                              *
(    53)    69      *             11                              *
(    54)    88      *        1   1                                *
(    55)    95      *          11 1                               *
```

```
(  56) 106    *            1 1                                      *
(  57) 107    *          1 1 1                                      *
(  58) 108    *          11        1                                *
==========    *=================================================*
(  59)   1    *                    1                               *
(  60)  14    *                   1                                *
(  61)  24    *        1              1                            *
(  62)  28    *                 1      11                          *
(  63)  51    *                 1      1                           *
(  64)  53    *                 11                                 *
(  65)  62    *                     1                              *
(  66)  63    *                    1                               *
(  67)  66    *                 1      1                           *
(  68)  71    *      1                 1                           *
(  69)  74    *                   1                                *
(  70)  75    *                    11                              *
(  71)  76    *                    1                               *
(  72)  77    *                     1                              *
(  73)  80    *                 1   1                              *
(  74)  82    *                     11                             *
(  75)  85    *            1        11                             *
(  76)  87    *                 1 11                               *
(  77)  97    *                 11 1                               *
==========    *=================================================*
(  78)  10    *                      1 1                           *
(  79)  11    *                       11   1          1           *
(  80)  12    *                    11                              *
(  81)  13    *                    1                               *
(  82)  22    *                     1   1                          *
(  83)  31    *                    1   1                           *
(  84)  32    *                    1   1 1                         *
(  85)  33    *                        11                          *
(  86)  43    *                    1   1 1                         *
(  87)  54    *                   1                                *
(  88)  55    *                    11                              *
(  89)  56    *                      1 1                           *
(  90)  79    *             1      11                              *
(  91)  81    *                    111                             *
(  92)  84    *                    11 1                            *
(  93)  86    *                    11  1                           *
(  94)  92    *                    11  1                           *
(  95)  93    *                    1   1                           *
(  96)  94    *                        1                           *
(  97)  96    *                    1   1 1                         *
(  98) 109    *                        1                           *
(  99) 116    *              1     1                               *
( 100) 117    *                    1  1                            *
==========    *=================================================*
( 101)  15    *                          1                        *
( 102)  20    *                          11                       *
( 103)  36    *                 1        1                        *
==========    *=================================================*
( 104)   4    *                              11                   *
( 105)   5    *                              1                    *
( 106)   7    *           1                  1                    *
( 107)  17    *                            1 1                    *
( 108)  18    *                            1                      *
( 109)  19    *            1               1 1                    *
( 110)  59    *                             1                     *
( 111)  60    *                               1                   *
( 112)  61    *                              1                    *
( 113)  73    *                            1                      *
( 114) 110    *  1                            1                   *
( 115) 112    *                            11                     *
```

```
( 116) 120  *                                                     1      *
=========== *============================================*
( 117)   2  *   1                       1                         1  *
( 118)   8  * 1                                                  11  *
( 119)  64  *                                                     1   *
( 120) 118  *                                                     1   *
=========== ********************************************
```

< Machine cells and Part families >
```
================================================================
Machine Cell[ 1] = { 1, 6, 7, 9, 16, 21, 23, 43 }
Machine Cell[ 2] = { 17, 18, 20, 25, 26, 27, 30, 33 }
Machine Cell[ 3] = { 5, 12, 28, 36, 38, 40, 41, 44 }
Machine Cell[ 4] = { 4, 8, 15, 29, 31, 32, 39, 45 }
Machine Cell[ 5] = { 3, 19 }
Machine Cell[ 6] = { 2, 10, 13, 34, 35, 37, 42 }
Machine Cell[ 7] = { 11, 14, 22, 24 }
================================================================
Part  Family[ 1] = { 3, 23, 25, 26, 27, 35, 37, 57, 67, 70, 72, 78, 83,
89, 90, 91, 98, 99, 100, 101, 102, 103, 104, 105, 111, 113, 114, 115, 119
}
Part  Family[ 2] = { 6, 9, 16, 21, 29, 30, 34, 38, 39, 40, 41, 42, 44, 45,
46, 47, 48, 49, 50, 52, 58, 65, 68, 69, 88, 95, 106, 107, 108 }
Part  Family[ 3] = { 1, 14, 24, 28, 51, 53, 62, 63, 66, 71, 74, 75, 76,
77, 80, 82, 85, 87, 97 }
Part  Family[ 4] = { 10, 11, 12, 13, 22, 31, 32, 33, 43, 54, 55, 56, 79,
81, 84, 86, 92, 93, 94, 96, 109, 116, 117 }
Part  Family[ 5] = { 15, 20, 36 }
Part  Family[ 6] = { 4, 5, 7, 17, 18, 19, 59, 60, 61, 73, 110, 112, 120 }
Part  Family[ 7] = { 2, 8, 64, 118 }
================================================================
```

< Summary of the performance measures >
```
================================================================
No. of machines                         = 45
No. of part types                       = 120
No. of cells                            = 7
Machine cell size                       = 8
Total no. of 1's in the original MPIM : |A| = 253
Matrix density                          = 0.0469
Total no. of within-block 1's           = 229
No. of exceptional elements (EEs)       = 24
No. of voids                            = 684
Sum of EEs and voids                    = 708
Group Cability Index (GCI)              = 90.51 %
grouping efficiency (GE)                = 62.27 %
Grouping efficacy (GF)                  = 24.44 %
Machine utilization (MU)                = 25.08 %
No. of redundant machines (RMs)         = 2
================================================================
```

```
Problem(117) --> Data file name :     DD_02_Gindy(1996)_45x120.cfp

< Machines visited by parts: Process route numbers(PRN) >
=================================================================
Part[   1] = {    5 }
Part[   2] = {    9,   40,   14 }
Part[   3] = {    9,   23 }
Part[   4] = {   13,   34 }
Part[   5] = {   13 }
Part[   6] = {   13,   27 }
Part[   7] = {   13,   26 }
Part[   8] = {    6,   11,   14 }
Part[   9] = {   30,   33 }
Part[  10] = {    4,   15 }
Part[  11] = {   22,   29,   31,   45 }
Part[  12] = {    4,    8 }
Part[  13] = {    4 }
Part[  14] = {   12 }
Part[  15] = {    3 }
Part[  16] = {    2,   27 }
Part[  17] = {    2,   13 }
Part[  18] = {    2 }
Part[  19] = {    2,   13,   27 }
Part[  20] = {    3,   19 }
Part[  21] = {   33 }
Part[  22] = {   15,   32 }
Part[  23] = {    7,   16 }
Part[  24] = {   21,   40 }
Part[  25] = {    5,    7 }
Part[  26] = {    6,    7,   23 }
Part[  27] = {    6,   23,   43 }
Part[  28] = {   41,   12,   44 }
Part[  29] = {   26 }
Part[  30] = {   25,   26 }
Part[  31] = {    4,   32 }
Part[  32] = {    4,   32,   45 }
Part[  33] = {   39,   45 }
Part[  34] = {   20 }
Part[  35] = {    7,    6,   16 }
Part[  36] = {    8,   19 }
Part[  37] = {    9,   21,   16 }
Part[  38] = {   17 }
Part[  39] = {   17,   26 }
Part[  40] = {   26,   30 }
Part[  41] = {   27,   33 }
Part[  42] = {   27 }
Part[  43] = {   15,   32,   45 }
Part[  44] = {   17,   33 }
Part[  45] = {   26,   27 }
Part[  46] = {   17,   27 }
Part[  47] = {   25,   27 }
Part[  48] = {   26,   27,   33 }
Part[  49] = {   17,   20,   27 }
Part[  50] = {   20,   27 }
Part[  51] = {    5,   41 }
Part[  52] = {   25,   26,   30 }
Part[  53] = {    5,   12 }
Part[  54] = {    8 }
Part[  55] = {    8,   15 }
Part[  56] = {   32,   45 }
Part[  57] = {   16,   42 }
Part[  58] = {   17,   20,   33 }
Part[  59] = {   34 }
Part[  60] = {   42 }
```

```
Part[  61] = {   35 }
Part[  62] = {   38 }
Part[  63] = {   36 }
Part[  64] = {   11 }
Part[  65] = {   25 }
Part[  66] = {    5,   40 }
Part[  67] = {    9,   41 }
Part[  68] = {   17,   25,   27 }
Part[  69] = {   27,   30 }
Part[  70] = {   16,   21 }
Part[  71] = {    9,   40 }
Part[  72] = {    9,   21,   16 }
Part[  73] = {   10 }
Part[  74] = {   28 }
Part[  75] = {   38,   40 }
Part[  76] = {   40 }
Part[  77] = {   41 }
Part[  78] = {   41,   43 }
Part[  79] = {    8,   15,   38 }
Part[  80] = {   28,   40 }
Part[  81] = {    8,   15,   29 }
Part[  82] = {   40,   41 }
Part[  83] = {    9,   43 }
Part[  84] = {    8,   15,   31 }
Part[  85] = {   30,   40,   41 }
Part[  86] = {    8,   15,   32 }
Part[  87] = {   28,   38,   40 }
Part[  88] = {   17,   25 }
Part[  89] = {    6,   16,   37 }
Part[  90] = {    1,    7,   16 }
Part[  91] = {    1,   16 }
Part[  92] = {    4,    8,   31 }
Part[  93] = {    4,   31 }
Part[  94] = {   39 }
Part[  95] = {   17,   18,   25 }
Part[  96] = {    3,   15,   32 }
Part[  97] = {   28,   36,   40 }
Part[  98] = {    9 }
Part[  99] = {    1,    6,   24 }
Part[ 100] = {    6,   16 }
Part[ 101] = {    1,    6,   14 }
Part[ 102] = {    1,    6,   23 }
Part[ 103] = {    1,    6,    7 }
Part[ 104] = {    1,   16,   43 }
Part[ 105] = {    6,   16,   35,   43 }
Part[ 106] = {   20,   26 }
Part[ 107] = {   17,   20,   26 }
Part[ 108] = {   17,   18,   33 }
Part[ 109] = {   32 }
Part[ 110] = {    7,   37 }
Part[ 111] = {    7,   43 }
Part[ 112] = {   34,   35 }
Part[ 113] = {    9,   16,   23 }
Part[ 114] = {    9,   16 }
Part[ 115] = {   16 }
Part[ 116] = {    4,   12 }
Part[ 117] = {    4,   29 }
Part[ 118] = {   14 }
Part[ 119] = {    1,    6,   16,   43 }
Part[ 120] = {   37 }
================================================================

        < Block Diagonal Solution Matrix >
                < Locations >
```

```
                    00000000000000000000000000000000000000000000000
                    00000000011111111112222222222333333333444444
                    12345678901234567890123456789012345678901234 5
                    < Machines >
                    0000000000000000000000000000000000000000000000000
                    0001234122223302233440012334011133401230141 12
 < Parts >          16763737056703918680148591252038452392952 4144
 ===========        *************************************************
 (    1)    23      *   11                                          *
 (    2)    25      *   1                                      1    *
 (    3)    26      *  11 1                                         *
 (    4)    27      *  1   1 1                                      *
 (    5)    35      *  111                                          *
 (    6)    57      *    1                            1            *
 (    7)    70      *    1           1                             *
 (    8)    78      *      1             1                         *
 (    9)    83      *      1         1                             *
 (   10)    89      *  1 1 1                                       *
 (   11)    90      *1 11                                          *
 (   12)    91      *1   1                                         *
 (   13)    99      *11                                           1*
 (   14)   100      *  1 1                                         *
 (   15)   101      *11                                         1  *
 (   16)   102      *11   1                                       *
 (   17)   103      *111                                          *
 (   18)   104      *1   1   1                                    *
 (   19)   105      *  1 1   1                          1         *
 (   20)   110      *    1   1                                    *
 (   21)   111      *    1   1                                    *
 (   22)   113      *      11         1                           *
 (   23)   115      *      1                                      *
 (   24)   119      *11 1   1                                     *
 (   25)   120      *          1                                  *
 ===========        *=============================================*
 (   26)     6      *                1             1               *
 (   27)     7      *              1               1               *
 (   28)     9      *                11                            *
 (   29)    16      *               1            1                 *
 (   30)    21      *                1                             *
 (   31)    29      *              1                               *
 (   32)    30      *              11                              *
 (   33)    34      *            1                                 *
 (   34)    38      *           1                                  *
 (   35)    39      *           1  1                               *
 (   36)    40      *              1 1                             *
 (   37)    41      *                1 1                           *
 (   38)    42      *                1                             *
 (   39)    44      *           1     1                            *
 (   40)    45      *              11                              *
 (   41)    46      *           1     1                            *
 (   42)    47      *             1 1                              *
 (   43)    48      *              11 1                            *
 (   44)    49      *          11  1                               *
 (   45)    50      *           1  1                               *
 (   46)    52      *            11 1                              *
 (   47)    58      *          11     1                            *
 (   48)    65      *             1                                *
 (   49)    68      *           1 1 1                              *
 (   50)    69      *               11                            *
 (   51)    88      *           1 1                                *
 (   52)    95      *           1 1                     1          *
 (   53)   106      *             1 1                              *
 (   54)   107      *           11 1                               *
 (   55)   108      *             1       1             1          *
```

```
==========  *========================================*
(   56)    2  *              1      1                    1  *
(   57)    3  *        1         1                          *
(   58)   24  *                 1    1                      *
(   59)   37  *     1          11                           *
(   60)   62  *                   1                         *
(   61)   63  *                  1                          *
(   62)   67  *              1      1                       *
(   63)   71  *              1      1                       *
(   64)   72  *     1          11                           *
(   65)   74  *                 1                           *
(   66)   75  *                 11                          *
(   67)   76  *                 1                           *
(   68)   77  *                  1                          *
(   69)   80  *               1   1                         *
(   70)   82  *                 11                          *
(   71)   85  *           1      11                         *
(   72)   87  *              1 11                           *
(   73)   97  *              11 1                           *
(   74)   98  *              1                              *
(   75)  114  *        1      1                             *
==========  *========================================*
(   76)   10  *                   1 1                       *
(   77)   11  *                    11 1          1          *
(   78)   12  *                  11                         *
(   79)   13  *                  1                          *
(   80)   22  *                   1   1                     *
(   81)   31  *                  1    1                     *
(   82)   32  *                  1    11                    *
(   83)   43  *                   1   11                    *
(   84)   54  *                 1                           *
(   85)   55  *                 11                          *
(   86)   56  *                    11                       *
(   87)   79  *             1    11                         *
(   88)   81  *                  111                        *
(   89)   84  *                  11 1                       *
(   90)   86  *                  11  1                      *
(   91)   92  *                 11   1                      *
(   92)   93  *                 1    1                      *
(   93)   96  *                  1   1        1             *
(   94)  109  *                      1                      *
(   95)  116  *                 1              1            *
(   96)  117  *                 1  1                        *
==========  *========================================*
(   97)    4  *                        1 1                  *
(   98)    5  *                        1                    *
(   99)   17  *                      1 1                    *
(  100)   18  *                        1                    *
(  101)   19  *          1           1 1                    *
(  102)   59  *                         1                   *
(  103)   60  *                          1                  *
(  104)   61  *                          1                  *
(  105)   73  *                       1                     *
(  106)  112  *                        11                   *
==========  *========================================*
(  107)   15  *                            1                *
(  108)   20  *                            11               *
(  109)   33  *                   1              1          *
(  110)   36  *              1               1              *
(  111)   94  *                             1               *
==========  *========================================*
(  112)    1  *                             1               *
(  113)   14  *                              1              *
(  114)   28  *                 1           11              *
```

```
( 115)  51  *                         1                    1      *
( 116)  53  *                                              11     *
( 117)  66  *                         1                    1      *
==========  *=================================================*
( 118)   8  * 1                                            11 *
( 119)  64  *                                               1 *
( 120) 118  *                                               1 *
==========  *************************************************
```

< Machine cells and Part families >
==
Machine Cell[1] = { 1, 6, 7, 16, 23, 37, 43 }
Machine Cell[2] = { 17, 20, 25, 26, 27, 30, 33 }
Machine Cell[3] = { 9, 21, 28, 36, 38, 40, 41 }
Machine Cell[4] = { 4, 8, 15, 29, 31, 32, 45 }
Machine Cell[5] = { 2, 10, 13, 18, 34, 35, 42 }
Machine Cell[6] = { 3, 19, 22, 39 }
Machine Cell[7] = { 5, 12, 44 }
Machine Cell[8] = { 11, 14, 24 }
==
Part Family[1] = { 23, 25, 26, 27, 35, 57, 70, 78, 83, 89, 90, 91, 99,
100, 101, 102, 103, 104, 105, 110, 111, 113, 115, 119, 120 }
Part Family[2] = { 6, 7, 9, 16, 21, 29, 30, 34, 38, 39, 40, 41, 42, 44,
45, 46, 47, 48, 49, 50, 52, 58, 65, 68, 69, 88, 95, 106, 107, 108 }
Part Family[3] = { 2, 3, 24, 37, 62, 63, 67, 71, 72, 74, 75, 76, 77, 80,
82, 85, 87, 97, 98, 114 }
Part Family[4] = { 10, 11, 12, 13, 22, 31, 32, 43, 54, 55, 56, 79, 81,
84, 86, 92, 93, 96, 109, 116, 117 }
Part Family[5] = { 4, 5, 17, 18, 19, 59, 60, 61, 73, 112 }
Part Family[6] = { 15, 20, 33, 36, 94 }
Part Family[7] = { 1, 14, 28, 51, 53, 66 }
Part Family[8] = { 8, 64, 118 }
==

< Summary of the performance measures >
==
No. of machines   = 45
No. of part types   = 120
No. of cells   = 8
Machine cell size   = 7
Total no. of 1's in the original MPIM : |A| = 253
Matrix density   = 0.0469
Total no. of within-block 1's   = 222
No. of exceptional elements (EEs)   = 31
No. of voids   = 567
Sum of EEs and voids   = 598
Group Cability Index (GCI)   = 87.75 %
grouping efficiency (GE)   = 63.73 %
Grouping efficacy (GF)   = 27.07 %
Machine utilization (MU)   = 28.14 %
No. of redundant machines (RMs)   = 3
==
```

```
Problem(117) --> Data file name :    DD_02_Gindy(1996)_45x120.cfp

< Machines visited by parts: Process route numbers(PRN) >
================================================================
Part[   1] = {    5 }
Part[   2] = {    9,   40,   14 }
Part[   3] = {    9,   23 }
Part[   4] = {   13,   34 }
Part[   5] = {   13 }
Part[   6] = {   13,   27 }
Part[   7] = {   13,   26 }
Part[   8] = {    6,   11,   14 }
Part[   9] = {   30,   33 }
Part[  10] = {    4,   15 }
Part[  11] = {   22,   29,   31,   45 }
Part[  12] = {    4,    8 }
Part[  13] = {    4 }
Part[  14] = {   12 }
Part[  15] = {    3 }
Part[  16] = {    2,   27 }
Part[  17] = {    2,   13 }
Part[  18] = {    2 }
Part[  19] = {    2,   13,   27 }
Part[  20] = {    3,   19 }
Part[  21] = {   33 }
Part[  22] = {   15,   32 }
Part[  23] = {    7,   16 }
Part[  24] = {   21,   40 }
Part[  25] = {    5,    7 }
Part[  26] = {    6,    7,   23 }
Part[  27] = {    6,   23,   43 }
Part[  28] = {   41,   12,   44 }
Part[  29] = {   26 }
Part[  30] = {   25,   26 }
Part[  31] = {    4,   32 }
Part[  32] = {    4,   32,   45 }
Part[  33] = {   39,   45 }
Part[  34] = {   20 }
Part[  35] = {    7,    6,   16 }
Part[  36] = {    8,   19 }
Part[  37] = {    9,   21,   16 }
Part[  38] = {   17 }
Part[  39] = {   17,   26 }
Part[  40] = {   26,   30 }
Part[  41] = {   27,   33 }
Part[  42] = {   27 }
Part[  43] = {   15,   32,   45 }
Part[  44] = {   17,   33 }
Part[  45] = {   26,   27 }
Part[  46] = {   17,   27 }
Part[  47] = {   25,   27 }
Part[  48] = {   26,   27,   33 }
Part[  49] = {   17,   20,   27 }
Part[  50] = {   20,   27 }
Part[  51] = {    5,   41 }
Part[  52] = {   25,   26,   30 }
Part[  53] = {    5,   12 }
Part[  54] = {    8 }
Part[  55] = {    8,   15 }
Part[  56] = {   32,   45 }
Part[  57] = {   16,   42 }
Part[  58] = {   17,   20,   33 }
Part[  59] = {   34 }
Part[  60] = {   42 }
```

```
Part[  61] = {   35 }
Part[  62] = {   38 }
Part[  63] = {   36 }
Part[  64] = {   11 }
Part[  65] = {   25 }
Part[  66] = {    5,   40 }
Part[  67] = {    9,   41 }
Part[  68] = {   17,   25,   27 }
Part[  69] = {   27,   30 }
Part[  70] = {   16,   21 }
Part[  71] = {    9,   40 }
Part[  72] = {    9,   21,   16 }
Part[  73] = {   10 }
Part[  74] = {   28 }
Part[  75] = {   38,   40 }
Part[  76] = {   40 }
Part[  77] = {   41 }
Part[  78] = {   41,   43 }
Part[  79] = {    8,   15,   38 }
Part[  80] = {   28,   40 }
Part[  81] = {    8,   15,   29 }
Part[  82] = {   40,   41 }
Part[  83] = {    9,   43 }
Part[  84] = {    8,   15,   31 }
Part[  85] = {   30,   40,   41 }
Part[  86] = {    8,   15,   32 }
Part[  87] = {   28,   38,   40 }
Part[  88] = {   17,   25 }
Part[  89] = {    6,   16,   37 }
Part[  90] = {    1,    7,   16 }
Part[  91] = {    1,   16 }
Part[  92] = {    4,    8,   31 }
Part[  93] = {    4,   31 }
Part[  94] = {   39 }
Part[  95] = {   17,   18,   25 }
Part[  96] = {    3,   15,   32 }
Part[  97] = {   28,   36,   40 }
Part[  98] = {    9 }
Part[  99] = {    1,    6,   24 }
Part[ 100] = {    6,   16 }
Part[ 101] = {    1,    6,   14 }
Part[ 102] = {    1,    6,   23 }
Part[ 103] = {    1,    6,    7 }
Part[ 104] = {    1,   16,   43 }
Part[ 105] = {    6,   16,   35,   43 }
Part[ 106] = {   20,   26 }
Part[ 107] = {   17,   20,   26 }
Part[ 108] = {   17,   18,   33 }
Part[ 109] = {   32 }
Part[ 110] = {    7,   37 }
Part[ 111] = {    7,   43 }
Part[ 112] = {   34,   35 }
Part[ 113] = {    9,   16,   23 }
Part[ 114] = {    9,   16 }
Part[ 115] = {   16 }
Part[ 116] = {    4,   12 }
Part[ 117] = {    4,   29 }
Part[ 118] = {   14 }
Part[ 119] = {    1,    6,   16,   43 }
Part[ 120] = {   37 }
===============================================================
```

< Block Diagonal Solution Matrix >
            < Locations >

```
                   0000000000000000000000000000000000000000000000
                   0000000000111111111122222222223333333333444444
                   1234567890123456789012345678901234567890123455
                   < Machines >
                   0000000000000000000000000000000000000000000000
                   0001241222230223340013341201334401223301 11413
 < Parts >         1676337056739186804851250452091423294 53149287
===========        *********************************************
(    1)     3      *    1         1                                *
(    2)    23      *   11                                          *
(    3)    26      *  11 1                                         *
(    4)    27      *  1   11                                       *
(    5)    35      * 111                                           *
(    6)    57      *    1                                    1     *
(    7)    83      *     1        1                                *
(    8)    89      *  1 1                                        1 *
(    9)    90      *1 11                                           *
(   10)    91      *1   1                                          *
(   11)    99      *11                     1                       *
(   12)   100      *  1 1                                          *
(   13)   101      *11                                      1      *
(   14)   102      *11   1                                         *
(   15)   103      *111                                            *
(   16)   104      *1   1 1                                        *
(   17)   105      *  1 1 1                               1        *
(   18)   111      *    1   1                                      *
(   19)   113      *     11        1                               *
(   20)   115      *     1                                         *
(   21)   119      *11 1 1                                         *
===========        *========================================*
(   22)    21      *              1                                *
(   23)    29      *            1                                  *
(   24)    30      *            11                                 *
(   25)    34      *           1                                   *
(   26)    38      *         1                                     *
(   27)    39      *         1  1                                  *
(   28)    41      *            11                                 *
(   29)    42      *            1                                  *
(   30)    44      *          1     1                              *
(   31)    45      *            11                                 *
(   32)    46      *          1    1                               *
(   33)    47      *           1 1                                 *
(   34)    48      *            111                                *
(   35)    49      *          11  1                                *
(   36)    50      *          1   1                                *
(   37)    52      *            11              1                  *
(   38)    58      *          11  1                                *
(   39)    65      *           1                                   *
(   40)    68      *          1 1 1                                *
(   41)    88      *          1 1                                  *
(   42)    95      *          1 1                            1     *
(   43)   106      *           1 1                                 *
(   44)   107      *          11 1                                 *
(   45)   108      *          1     1                        1     *
===========        *========================================*
(   46)     2      *                1    1                   1     *
(   47)    24      *                 1    1                         *
(   48)    37      *       1        11                              *
(   49)    62      *                  1                            *
(   50)    63      *                 1                             *
(   51)    66      *                  1       1                    *
(   52)    70      *       1        1                              *
(   53)    71      *                1    1                         *
(   54)    72      *       1        11                             *
```

```
(  55)    74   *                       1                                    *
(  56)    75   *                         11                                 *
(  57)    76   *                          1                                 *
(  58)    80   *                        1   1                               *
(  59)    87   *                        1 11                                *
(  60)    97   *                        11 1                                *
(  61)    98   *                     1                                      *
(  62)   114   *        1            1                                      *
==========    *==========================================================*
(  63)    10   *                          1 1                              *
(  64)    12   *                          11                               *
(  65)    13   *                          1                                *
(  66)    22   *                         1 1                               *
(  67)    31   *                        1    1                             *
(  68)    32   *                        1    11                            *
(  69)    43   *                         1 11                              *
(  70)    54   *                        1                                  *
(  71)    55   *                        11                                 *
(  72)    56   *                          11                               *
(  73)    79   *                    1   11                                 *
(  74)    81   *                        11            1                    *
(  75)    84   *                        111                                *
(  76)    86   *                        11 1                               *
(  77)    92   *                       11 1                                *
(  78)    93   *                        1  1                               *
(  79)    96   *                          1 1              1               *
(  80)   109   *                        1                                  *
==========    *==========================================================*
(  81)    73   *                            1                              *
==========    *==========================================================*
(  82)     1   *                           1                               *
(  83)     9   *              1              1                             *
(  84)    14   *                            1                              *
(  85)    25   *     1                      1                              *
(  86)    28   *                            1  11                          *
(  87)    33   *                         1     1                           *
(  88)    40   *              1              1                             *
(  89)    51   *                          1    1                           *
(  90)    53   *                          11                               *
(  91)    67   *               1                 1                         *
(  92)    69   *              1                 1                          *
(  93)    77   *                                1                          *
(  94)    78   *        1                        1                         *
(  95)    82   *                      1          1                         *
(  96)    85   *                      1        1 1                         *
(  97)    94   *                               1                           *
(  98)   116   *                  1          1                             *
==========    *==========================================================*
(  99)     4   *                                 1   1                     *
( 100)     5   *                                 1                         *
( 101)     6   *              1                   1                         *
( 102)     7   *             1                    1                         *
( 103)    11   *                     1 1           11                      *
( 104)    16   *               1                 1                          *
( 105)    17   *                                 11                         *
( 106)    18   *                                 1                          *
( 107)    19   *               1                 11                         *
( 108)    59   *                                   1                       *
( 109)    61   *                                    1                      *
( 110)   112   *                                   11                       *
( 111)   117   *                     1              1                       *
==========    *==========================================================*
( 112)     8   * 1                                          11             *
( 113)    15   *                                            1              *
```

```
( 114)  20    *                                                    1  1     *
( 115)  36    *                              1                         1     *
( 116)  60    *                                                        1     *
( 117)  64    *                                                     1        *
( 118) 118    *                                                        1     *
==========    *========================================================*
( 119) 110    *    1                                                        1*
( 120) 120    *                                                             1*
==========    ************************************************************
```

< Machine cells and Part families >
```
================================================================
Machine Cell[ 1] = { 1, 6, 7, 16, 23, 43 }
Machine Cell[ 2] = { 17, 20, 25, 26, 27, 33 }
Machine Cell[ 3] = { 9, 21, 28, 36, 38, 40 }
Machine Cell[ 4] = { 4, 8, 15, 31, 32, 45 }
Machine Cell[ 5] = { 10, 24 }
Machine Cell[ 6] = { 5, 12, 30, 39, 41, 44 }
Machine Cell[ 7] = { 2, 13, 22, 29, 34, 35 }
Machine Cell[ 8] = { 3, 11, 14, 19, 42 }
Machine Cell[ 9] = { 18, 37 }
================================================================
Part  Family[ 1] = { 3, 23, 26, 27, 35, 57, 83, 89, 90, 91, 99, 100, 101,
102, 103, 104, 105, 111, 113, 115, 119 }
Part  Family[ 2] = { 21, 29, 30, 34, 38, 39, 41, 42, 44, 45, 46, 47, 48,
49, 50, 52, 58, 65, 68, 88, 95, 106, 107, 108 }
Part  Family[ 3] = { 2, 24, 37, 62, 63, 66, 70, 71, 72, 74, 75, 76, 80,
87, 97, 98, 114 }
Part  Family[ 4] = { 10, 12, 13, 22, 31, 32, 43, 54, 55, 56, 79, 81, 84,
86, 92, 93, 96, 109 }
Part  Family[ 5] = { 73 }
Part  Family[ 6] = { 1, 9, 14, 25, 28, 33, 40, 51, 53, 67, 69, 77, 78, 82,
85, 94, 116 }
Part  Family[ 7] = { 4, 5, 6, 7, 11, 16, 17, 18, 19, 59, 61, 112, 117 }
Part  Family[ 8] = { 8, 15, 20, 36, 60, 64, 118 }
Part  Family[ 9] = { 110, 120 }
================================================================
```

< Summary of the performance measures >
```
================================================================
No. of machines                          = 45
No. of part types                        = 120
No. of cells                             = 9
Machine cell size                        = 6
Total no. of 1's in the original MPIM : |A| = 253
Matrix density                           = 0.0469
Total no. of within-block 1's            = 213
No. of exceptional elements (EEs)        = 40
No. of voids                             = 488
Sum of EEs and voids                     = 528
Group Cability Index (GCI)               = 84.19 %
grouping efficiency (GE)                 = 64.77 %
Grouping efficacy (GF)                   = 28.74 %
Machine utilization (MU)                 = 30.39 %
No. of redundant machines (RMs)          = 2
================================================================
```

```
Problem(117) --> Data file name :    DD_02_Gindy(1996)_45x120.cfp

< Machines visited by parts: Process route numbers(PRN) >
=================================================================
Part[   1] = {     5 }
Part[   2] = {     9,   40,   14 }
Part[   3] = {     9,   23 }
Part[   4] = {    13,   34 }
Part[   5] = {    13 }
Part[   6] = {    13,   27 }
Part[   7] = {    13,   26 }
Part[   8] = {     6,   11,   14 }
Part[   9] = {    30,   33 }
Part[  10] = {     4,   15 }
Part[  11] = {    22,   29,   31,   45 }
Part[  12] = {     4,    8 }
Part[  13] = {     4 }
Part[  14] = {    12 }
Part[  15] = {     3 }
Part[  16] = {     2,   27 }
Part[  17] = {     2,   13 }
Part[  18] = {     2 }
Part[  19] = {     2,   13,   27 }
Part[  20] = {     3,   19 }
Part[  21] = {    33 }
Part[  22] = {    15,   32 }
Part[  23] = {     7,   16 }
Part[  24] = {    21,   40 }
Part[  25] = {     5,    7 }
Part[  26] = {     6,    7,   23 }
Part[  27] = {     6,   23,   43 }
Part[  28] = {    41,   12,   44 }
Part[  29] = {    26 }
Part[  30] = {    25,   26 }
Part[  31] = {     4,   32 }
Part[  32] = {     4,   32,   45 }
Part[  33] = {    39,   45 }
Part[  34] = {    20 }
Part[  35] = {     7,    6,   16 }
Part[  36] = {     8,   19 }
Part[  37] = {     9,   21,   16 }
Part[  38] = {    17 }
Part[  39] = {    17,   26 }
Part[  40] = {    26,   30 }
Part[  41] = {    27,   33 }
Part[  42] = {    27 }
Part[  43] = {    15,   32,   45 }
Part[  44] = {    17,   33 }
Part[  45] = {    26,   27 }
Part[  46] = {    17,   27 }
Part[  47] = {    25,   27 }
Part[  48] = {    26,   27,   33 }
Part[  49] = {    17,   20,   27 }
Part[  50] = {    20,   27 }
Part[  51] = {     5,   41 }
Part[  52] = {    25,   26,   30 }
Part[  53] = {     5,   12 }
Part[  54] = {     8 }
Part[  55] = {     8,   15 }
Part[  56] = {    32,   45 }
Part[  57] = {    16,   42 }
Part[  58] = {    17,   20,   33 }
Part[  59] = {    34 }
Part[  60] = {    42 }
```

```
Part[  61] = {   35 }
Part[  62] = {   38 }
Part[  63] = {   36 }
Part[  64] = {   11 }
Part[  65] = {   25 }
Part[  66] = {    5,   40 }
Part[  67] = {    9,   41 }
Part[  68] = {   17,   25,   27 }
Part[  69] = {   27,   30 }
Part[  70] = {   16,   21 }
Part[  71] = {    9,   40 }
Part[  72] = {    9,   21,   16 }
Part[  73] = {   10 }
Part[  74] = {   28 }
Part[  75] = {   38,   40 }
Part[  76] = {   40 }
Part[  77] = {   41 }
Part[  78] = {   41,   43 }
Part[  79] = {    8,   15,   38 }
Part[  80] = {   28,   40 }
Part[  81] = {    8,   15,   29 }
Part[  82] = {   40,   41 }
Part[  83] = {    9,   43 }
Part[  84] = {    8,   15,   31 }
Part[  85] = {   30,   40,   41 }
Part[  86] = {    8,   15,   32 }
Part[  87] = {   28,   38,   40 }
Part[  88] = {   17,   25 }
Part[  89] = {    6,   16,   37 }
Part[  90] = {    1,    7,   16 }
Part[  91] = {    1,   16 }
Part[  92] = {    4,    8,   31 }
Part[  93] = {    4,   31 }
Part[  94] = {   39 }
Part[  95] = {   17,   18,   25 }
Part[  96] = {    3,   15,   32 }
Part[  97] = {   28,   36,   40 }
Part[  98] = {    9 }
Part[  99] = {    1,    6,   24 }
Part[ 100] = {    6,   16 }
Part[ 101] = {    1,    6,   14 }
Part[ 102] = {    1,    6,   23 }
Part[ 103] = {    1,    6,    7 }
Part[ 104] = {    1,   16,   43 }
Part[ 105] = {    6,   16,   35,   43 }
Part[ 106] = {   20,   26 }
Part[ 107] = {   17,   20,   26 }
Part[ 108] = {   17,   18,   33 }
Part[ 109] = {   32 }
Part[ 110] = {    7,   37 }
Part[ 111] = {    7,   43 }
Part[ 112] = {   34,   35 }
Part[ 113] = {    9,   16,   23 }
Part[ 114] = {    9,   16 }
Part[ 115] = {   16 }
Part[ 116] = {    4,   12 }
Part[ 117] = {    4,   29 }
Part[ 118] = {   14 }
Part[ 119] = {    1,    6,   16,   43 }
Part[ 120] = {   37 }
================================================================

        < Block Diagonal Solution Matrix >
                < Locations >
```

```
                         0000000000000000000000000000000000000000000
                         0000000000111111111122222222223333333333444444
                         1234567890123456789012345678901234567890123455
                         < Machines >
                         0000000000000000000000000000000000000000000000
                         0001412222233440013300114230133401122133122334
        < Parts >        1676370567868014851235294472345291413803020995
        ==========       *******************************************
(     1)    23   *   11                                               *
(     2)    25   *   1                         1                      *
(     3)    26   *  11                                         1      *
(     4)    27   *  1  1                                       1      *
(     5)    35   *  111                                               *
(     6)    57   *    1                                  1            *
(     7)    70   *    1                                     1         *
(     8)    78   *     1              1                               *
(     9)    89   *  1 1                         1                     *
(    10)    90   *1 11                                                *
(    11)    91   *1  1                                                *
(    12)    99   *11                          1                       *
(    13)   100   *  1 1                                               *
(    14)   101   *11                                       1          *
(    15)   102   *11                                         1        *
(    16)   103   *111                                                 *
(    17)   104   *1   11                                              *
(    18)   105   *  1  11                           1                 *
(    19)   110   *    1                         1                     *
(    20)   111   *    1 1                                             *
(    21)   114   *     1                               1              *
(    22)   115   *     1                                              *
(    23)   119   *11  11                                              *
        ==========       *===========================================*
(    24)     6   *             1                  1                   *
(    25)     7   *            1                   1                   *
(    26)    16   *            1                 1                     *
(    27)    29   *            1                                       *
(    28)    30   *           11                                       *
(    29)    34   *          1                                         *
(    30)    38   *          1                                         *
(    31)    39   *          1   1                                     *
(    32)    41   *             1                          1           *
(    33)    42   *             1                                      *
(    34)    44   *          1                             1           *
(    35)    45   *            11                                      *
(    36)    46   *          1    1                                    *
(    37)    47   *            1 1                                      *
(    38)    48   *            11                          1           *
(    39)    49   *          11   1                                    *
(    40)    50   *           1   1                                    *
(    41)    52   *            11                             1        *
(    42)    58   *          11                               1        *
(    43)    65   *            1                                       *
(    44)    68   *          1 1 1                                     *
(    45)    69   *             1                            1         *
(    46)    88   *          1 1                                       *
(    47)    95   *          1 1                             1         *
(    48)   106   *           1 1                                      *
(    49)   107   *          11 1                                      *
        ==========       *===========================================*
(    50)    24   *               1                        1           *
(    51)    51   *                1         1                         *
(    52)    62   *             1                                      *
(    53)    63   *            1                                       *
(    54)    66   *               1           1                        *
```

```
(  55)   71    *              1                    1                    *
(  56)   74    *            1                                           *
(  57)   75    *              11                                        *
(  58)   76    *              1                                         *
(  59)   77    *               1                                        *
(  60)   80    *            1  1                                        *
(  61)   82    *              11                                        *
(  62)   85    *              11                        1               *
(  63)   87    *            1 11                                        *
(  64)   97    *            11 1                                        *
==========    *==========================================================*
(  65)   10    *                   1 1                                  *
(  66)   12    *                   11                                   *
(  67)   13    *                   1                                    *
(  68)   22    *                    1 1                                 *
(  69)   31    *                   1   1                                *
(  70)   32    *                   1   1                              1*
(  71)   43    *                    1 1                               1*
(  72)   54    *                   1                                    *
(  73)   55    *                   11                                   *
(  74)   79    *            1     11                                    *
(  75)   81    *                   11                        1          *
(  76)   84    *                   111                                  *
(  77)   86    *                   11 1                                 *
(  78)   92    *                  11 1                                  *
(  79)   93    *                  1  1                                  *
(  80)   96    *                    1 11                                *
(  81)  109    *                     1                                  *
(  82)  116    *                  1       1                             *
==========    *==========================================================*
(  83)    1    *                      1                                 *
(  84)   14    *                       1                                *
(  85)   15    *                     1                                  *
(  86)   20    *                     1   1                              *
(  87)   28    *                1       1 1                             *
(  88)   36    *                    1     1                             *
(  89)   53    *                       11                               *
==========    *==========================================================*
(  90)  120    *                             1                          *
==========    *==========================================================*
(  91)    4    *                               11                       *
(  92)    5    *                               1                        *
(  93)   17    *                               11                       *
(  94)   18    *                               1                        *
(  95)   19    *            1                  11                       *
(  96)   59    *                                1                       *
(  97)   60    *                                 1                      *
(  98)   61    *                                1                       *
(  99)  112    *                               11                       *
==========    *==========================================================*
( 100)    2    *                1                   1 1                  *
( 101)    3    *                                    1   1               *
( 102)    8    * 1                                    11                *
( 103)   37    *    1                               1  1                *
( 104)   64    *                                    1                   *
( 105)   67    *                 1                  1                    *
( 106)   72    *     1                              1  1                 *
( 107)   83    *      1                             1                    *
( 108)   98    *                                    1                    *
( 109)  113    *     1                              1   1                *
( 110)  118    *                                     1                   *
==========    *==========================================================*
( 111)    9    *                                         11             *
( 112)   21    *                                          1             *
```

```
( 113)  40   *           1                                1       *
( 114) 108   *        1                              1 1       *
==========   *===============================================*
( 115)  11   *                      1                      11 1*
( 116)  33   *                                             11*
( 117)  56   *                   1                          1*
( 118)  73   *                                         1     *
( 119)  94   *                                         1   *
( 120) 117   *                    1                        1   *
==========   *************************************************
```

< Machine cells and Part families >
==
Machine Cell[1] = { 1, 6, 7, 16, 43 }
Machine Cell[2] = { 17, 20, 25, 26, 27 }
Machine Cell[3] = { 28, 36, 38, 40, 41 }
Machine Cell[4] = { 4, 8, 15, 31, 32 }
Machine Cell[5] = { 3, 5, 12, 19, 44 }
Machine Cell[6] = { 24, 37 }
Machine Cell[7] = { 2, 13, 34, 35, 42 }
Machine Cell[8] = { 9, 11, 14, 21, 23 }
Machine Cell[9] = { 18, 30, 33 }
Machine Cell[10] = { 10, 22, 29, 39, 45 }
==
Part Family[1] = { 23, 25, 26, 27, 35, 57, 70, 78, 89, 90, 91, 99, 100,
101, 102, 103, 104, 105, 110, 111, 114, 115, 119 }
Part Family[2] = { 6, 7, 16, 29, 30, 34, 38, 39, 41, 42, 44, 45, 46, 47,
48, 49, 50, 52, 58, 65, 68, 69, 88, 95, 106, 107 }
Part Family[3] = { 24, 51, 62, 63, 66, 71, 74, 75, 76, 77, 80, 82, 85,
87, 97 }
Part Family[4] = { 10, 12, 13, 22, 31, 32, 43, 54, 55, 79, 81, 84, 86,
92, 93, 96, 109, 116 }
Part Family[5] = { 1, 14, 15, 20, 28, 36, 53 }
Part Family[6] = { 120 }
Part Family[7] = { 4, 5, 17, 18, 19, 59, 60, 61, 112 }
Part Family[8] = { 2, 3, 8, 37, 64, 67, 72, 83, 98, 113, 118 }
Part Family[9] = { 9, 21, 40, 108 }
Part Family[10] = { 11, 33, 56, 73, 94, 117 }
==

< Summary of the performance measures >
==
No. of machines   = 45
No. of part types   = 120
No. of cells   = 10
Machine cell size   = 5
Total no. of 1's in the original MPIM : |A| = 253
Matrix density   = 0.0469
Total no. of within-block 1's   = 204
No. of exceptional elements (EEs)   = 49
No. of voids   = 385
Sum of EEs and voids   = 434
Group Cability Index (GCI)   = 80.63 %
grouping efficiency (GE)   = 66.81 %
Grouping efficacy (GF)   = 31.97 %
Machine utilization (MU)   = 34.63 %
No. of redundant machines (RMs)   = 1
==

```
Problem(118) --> Data file name :    DD_03_Nair(1996_Figure_12)_46x97.cfp

< Machines visited by parts: Process route numbers(PRN) >
=================================================================
Part[   1] = {   1,  20 }
Part[   2] = {  40,  42,  26 }
Part[   3] = {  36 }
Part[   4] = {   2,   9,  17,  31,  41,  16 }
Part[   5] = {   6,  10,  14,  19,  46 }
Part[   6] = {   2,   5,  23,  34 }
Part[   7] = {   8,   6,  14,  19 }
Part[   8] = {  15,  22,  35 }
Part[   9] = {   1,   5,  23,  34,  22 }
Part[  10] = {   4,  40,  42,  26 }
Part[  11] = {  39,  25,  37 }
Part[  12] = {   3,  20,  28,  30,  33,  23,  16 }
Part[  13] = {  11,  27,  45 }
Part[  14] = {  43,   9,  10,  14,  46 }
Part[  15] = {   8,  17,  41,  11 }
Part[  16] = {  33,   6,  10,  19,  46,  35 }
Part[  17] = {  36,  15 }
Part[  18] = {   6,  19 }
Part[  19] = {  29,  22 }
Part[  20] = {  36,   4,  26,  11 }
Part[  21] = {  16,  27,  21,  29,  22,  35 }
Part[  22] = {   4,  42 }
Part[  23] = {  42 }
Part[  24] = {   2,  30,   4,  40,  42,  14 }
Part[  25] = {  41,  14,  19,  46,  13 }
Part[  26] = {  43,   9,  31,  41,  28 }
Part[  27] = {  34,   6,  10,  46 }
Part[  28] = {   1,  17,  40,  19,  39 }
Part[  29] = {  44,   2,  17,  32,  26 }
Part[  30] = {  24,  39,  25,  37,  45,  29 }
Part[  31] = {   4,  38,  12,  16,  13 }
Part[  32] = {  20,  42,  26,  12 }
Part[  33] = {   2,   9,  31,  41,  40,  38 }
Part[  34] = {   1,  43,  44,  11,  35 }
Part[  35] = {   3,   5,  34,  18 }
Part[  36] = {  34,  24,  39 }
Part[  37] = {  12,  16,  27,  22 }
Part[  38] = {   9,  17,  23,  34,  18 }
Part[  39] = {   5,  23,  34,   6,  37 }
Part[  40] = {   3,  20,  33,  24 }
Part[  41] = {   4,  46,  29,  15,  22,  35 }
Part[  42] = {   3,  20,  30,  40 }
Part[  43] = {   8,   7,  40,  21 }
Part[  44] = {  10,  15,  22 }
Part[  45] = {  38,  24,  13 }
Part[  46] = {   2,  17,  39 }
Part[  47] = {  28,  30,  33,  27 }
Part[  48] = {   1,  36,  43,   9 }
Part[  49] = {   5,  34,  18 }
Part[  50] = {  26,  12,  11,  27,  45,  13 }
Part[  51] = {  18,  21,  29 }
Part[  52] = {  12,  16 }
Part[  53] = {   4,  40 }
Part[  54] = {   6,  10,  19,  46 }
Part[  55] = {  44,  38,  16,  29 }
Part[  56] = {  23,  24,  39,  25 }
Part[  57] = {   8,  23,  37 }
Part[  58] = {   6,  14,  19,  16 }
Part[  59] = {   1,   9,  10,  29,  15,  22,  35 }
Part[  60] = {  31,  11,  27,  21 }
```

```
Part[ 61] = {  24,  39,  25 }
Part[ 62] = {  17,   4,  40,  42,  26,  16 }
Part[ 63] = {  10,  14,  19,  46 }
Part[ 64] = {   8,  20,  28,  33,  37,  21,  22 }
Part[ 65] = {   2,  20,  40,  26 }
Part[ 66] = {   4,  40 }
Part[ 67] = {   5,  23,  34,  18,  16,  45,  15 }
Part[ 68] = {  43,  23,  18 }
Part[ 69] = {  31,  33,  38,  12,  16 }
Part[ 70] = {   4,  40,  42,  26,  13,  29 }
Part[ 71] = {  13 }
Part[ 72] = {   8,  10,  21 }
Part[ 73] = {  38,  12,  16,  24 }
Part[ 74] = {   8,  28,  33 }
Part[ 75] = {  36,  32,   5,  14 }
Part[ 76] = {  31,  20,   5,  11,  13 }
Part[ 77] = {   3,  28,  33,  19 }
Part[ 78] = {  44,  31,  26,  14,  21 }
Part[ 79] = {  36,  32 }
Part[ 80] = {   1,  43 }
Part[ 81] = {  24,  39,  25,  37 }
Part[ 82] = {  44,   3,  20,  28,  25,  21 }
Part[ 83] = {  30,   5,  18 }
Part[ 84] = {   5,  23,  38 }
Part[ 85] = {  24,  39 }
Part[ 86] = {   9,   6,  10,  14,  46,  24 }
Part[ 87] = {  36,   7,   6,  38 }
Part[ 88] = {   3,  20,  28,  30,  33,  32 }
Part[ 89] = {   2,   9,  17,  31,  41,   7,  25,  35 }
Part[ 90] = {  12,  24,  27,  13 }
Part[ 91] = {  38,  25 }
Part[ 92] = {  34,  11,  45,  13 }
Part[ 93] = {   9,  17,  31,   5,  14 }
Part[ 94] = {  27,  13 }
Part[ 95] = {   2,   9,  41,  32 }
Part[ 96] = {   3,  33,  22 }
Part[ 97] = {  40,  42,  26,  46 }
================================================================
```

< Block Diagonal Solution Matrix >
```
              < Locations >
              000000000000000000000000000000000000000000000000
              000000000011111111112222222222333333333344444444
              123456789012345678901234567890123456789012345678
              < Machines >
              000000000000000000000000000000000000000000000000
              012302442233002233012234033111123440111240 0134
< Parts >     583446024579380803152953726123678456 0491629711
===========   ************************************************
(    1)    6  *1 11                                      1     *
(    2)    9  *1 11               1 1                          *
(    3)   35  *11 1          1                                 *
(    4)   38  * 111                                      11    *
(    5)   39  *1 11        1                          1        *
(    6)   49  *11 1                                           *
(    7)   51  * 1                1                    1        *
(    8)   67  *1111                  1       1   1            *
(    9)   68  * 11                         1                   *
(   10)   83  *11                 1                            *
(   11)   84  *1 1                                 1          *
===========   *============================================*
(   12)    2  *     111                                        *
(   13)   10  *     1111                                       *
(   14)   20  *     11                     11                  *
```

```
(   15)   22   *     1   1                                              *
(   16)   23   *         1                                              *
(   17)   24   *     1 11            1                      1     1     *
(   18)   28   *       1     1       1                  1       1       *
(   19)   32   *      1 1        1       1                  1           *
(   20)   53   *     1 1                                                *
(   21)   62   *     1111                        1              1       *
(   22)   65   *       11          1                        1          *
(   23)   66   *     1 1                                                *
(   24)   70   *     1111                 1          1                  *
(   25)   97   *     111                                     1         *
==========   *==========================================================*
(   26)   11   *         111                                            *
(   27)   30   *         1111          1              1                 *
(   28)   36   *    1    1 1                                            *
(   29)   56   *   1     11 1                                           *
(   30)   61   *         11 1                                           *
(   31)   81   *         1111                                           *
(   32)   85   *         1 1                                            *
(   33)   91   *          1                        1                    *
==========   *==========================================================*
(   34)    1   *          1   1                                         *
(   35)   12   *    1        1 1111               1                     *
(   36)   40   *        1    1 1  1                                     *
(   37)   42   *       1      1 1 1                                     *
(   38)   43   *       1        1         1                 1           *
(   39)   47   *                111            1                        *
(   40)   57   *    1        1  1                                       *
(   41)   64   *            1   111 1   1                     1         *
(   42)   74   *             1 1 1                                      *
(   43)   77   *             1   1 1                    1               *
(   44)   82   *        1   1 11                   1        1           *
(   45)   88   *          1 1111          1                             *
(   46)   96   *          1     1  1                                    *
==========   *==========================================================*
(   47)    8   *               11 1                                     *
(   48)   19   *               11                                       *
(   49)   21   *               111        11       1                    *
(   50)   34   *           1    11     1       1                        *
(   51)   41   *       1       1111                     1               *
(   52)   44   *               11                 1                     *
(   53)   48   *            1    1   1                        1         *
(   54)   59   *            11111           1          1               *
(   55)   80   *            1      1                                    *
==========   *==========================================================*
(   56)    3   *                     1                                  *
(   57)   17   *              1      1                                  *
(   58)   75   *1                  11         1                         *
(   59)   79   *                   11                                   *
(   60)   87   *                  1 1       1  1                        *
==========   *==========================================================*
(   61)   13   *                        1    1  1                       *
(   62)   31   *     1                    111 1                         *
(   63)   37   *                   1       1 11                         *
(   64)   45   *       1                    1 1                         *
(   65)   50   *      1                   111 1  1                      *
(   66)   52   *                          1 1                           *
(   67)   55   *                  1         1 11                        *
(   68)   60   *                     1       1       1      1    *
(   69)   69   *              1            1 1 1              1  *
(   70)   71   *                            1                           *
(   71)   73   *         1                 1 1 1                        *
(   72)   76   *1             1           1 1               1  *
(   73)   90   *         1                 11 1                         *
```

```
(  74)  92  *    1                              1 1    1              *
(  75)  94  *                                     1 1                 *
==========  *===============================================*
==========  *===============================================*
(  76)   5  *                                        1111 1           *
(  77)   7  *                1                        1 11            *
(  78)  14  *                      1                  11   1 1        *
(  79)  16  *                   1     1               11 1 1          *
(  80)  18  *                                         1  1            *
(  81)  25  *                           1             11 1       1*
(  82)  27  *    1                                    11   1          *
(  83)  54  *                                         11 1 1          *
(  84)  58  *                           1             1 11            *
(  85)  63  *                                         111 1           *
(  86)  72  *                1                          1  1          *
(  87)  78  *         1                              1   1 1      1 *
(  88)  86  *            1                           111   1 1        *
==========  *===============================================*
(  89)   4  *                                  1         11111*
(  90)  15  *                1                 1            1 1*
(  91)  26  *                   1        1                 1 11*
(  92)  29  *      1                  1           1        1 1   *
(  93)  33  *        1                               1     11 11*
(  94)  46  *            1                              1 1   *
(  95)  89  *          1                1 1              11111*
(  96)  93  *1                                     1     111  *
(  97)  95  *                                1             11  1*
==========  ***********************************************
```

< Machine cells and Part families >
```
===================================================================
Machine Cell[ 1] = { 5, 18, 23, 34 }
Machine Cell[ 2] = { 4, 26, 40, 42 }
Machine Cell[ 3] = { 24, 25, 37, 39 }
Machine Cell[ 4] = { 3, 8, 20, 28, 30, 33 }
Machine Cell[ 5] = { 1, 15, 22, 29, 35, 43 }
Machine Cell[ 6] = { 7, 32, 36 }
Machine Cell[ 7] = { 11, 12, 13, 16, 27, 38 }
Machine Cell[ 8] = { 44, 45 }   --> Residual cell
Machine Cell[ 9] = { 6, 10, 14, 19, 21, 46 }
Machine Cell[10] = { 2, 9, 17, 31, 41 }
===================================================================
Part  Family[ 1] = { 6, 9, 35, 38, 39, 49, 51, 67, 68, 83, 84 }
Part  Family[ 2] = { 2, 10, 20, 22, 23, 24, 28, 32, 53, 62, 65, 66, 70, 97
}
Part  Family[ 3] = { 11, 30, 36, 56, 61, 81, 85, 91 }
Part  Family[ 4] = { 1, 12, 40, 42, 43, 47, 57, 64, 74, 77, 82, 88, 96 }
Part  Family[ 5] = { 8, 19, 21, 34, 41, 44, 48, 59, 80 }
Part  Family[ 6] = { 3, 17, 75, 79, 87 }
Part  Family[ 7] = { 13, 31, 37, 45, 50, 52, 55, 60, 69, 71, 73, 76, 90,
92, 94 }
Part  Family[ 8] --> Empty Part family
Part  Family[ 9] = { 5, 7, 14, 16, 18, 25, 27, 54, 58, 63, 72, 78, 86 }
Part  Family[10] = { 4, 15, 26, 29, 33, 46, 89, 93, 95 }
===================================================================
```

< Summary of the performance measures >
```
===================================================================
No. of machines                            = 46
No. of part types                          = 97
No. of cells                               = 10
Machine cell size                          = 6
Total no. of 1's in the original MPIM : |A| = 392
Matrix density                             = 0.0879
```

```
Total no. of within-block 1's          = 265
No. of exceptional elements (EEs)       = 127
No. of voids                            = 227
Sum of EEs and voids                    = 354
Group Cability Index (GCI)              = 67.60 %
grouping efficiency (GE)                = 75.33 %
Grouping efficacy (GF)                  = 42.81 %
Machine utilization (MU)                = 53.86 %
No. of redundant machines (RMs)         = 2
============================================================
```

```
Problem(119) --> Data file name :    DD_04_Nair(1996_Figure_14)_46x100.cfp

< Machines visited by parts: Process route numbers(PRN) >
========================================================
Part[  1] = {   8,  21,  22 }
Part[  2] = {   4,  26,  40,  42 }
Part[  3] = {  31,   7,  32,  36 }
Part[  4] = {   2,   9,  17,  31,  41,  33 }
Part[  5] = {   6,  10,  14,  19,  46 }
Part[  6] = {  15,  22,  29,  35,  25 }
Part[  7] = {  20,   6,  10,  14,  19,  46 }
Part[  8] = {   5,  18,  23,  34 }
Part[  9] = {   9,   5,  18,  23,  34 }
Part[ 10] = {   4,  26,  40,  42 }
Part[ 11] = {  24,  25,  37,  39 }
Part[ 12] = {   2,   3,  20,  28,  30,  33 }
Part[ 13] = {  11,  13,  27,  45 }
Part[ 14] = {   1,   6,  10,  14,  19,  46 }
Part[ 15] = {   2,   9,  17,  31,  41,  34 }
Part[ 16] = {   6,  10,  14,  19,  46 }
Part[ 17] = {  15,  22,  29,  35 }
Part[ 18] = {   6,  10,  14,  19,  46 }
Part[ 19] = {  15,  22,  29,  35 }
Part[ 20] = {   4,  26,  40,  42 }
Part[ 21] = {   3,  15,  22,  29,  35 }
Part[ 22] = {   4,  26,  40,  42 }
Part[ 23] = {   4,  26,  40,  42 }
Part[ 24] = {   1,   4,  26,  40,  42 }
Part[ 25] = {   6,  10,  14,  19,  46,  39 }
Part[ 26] = {   2,   9,  17,  31,  41,  20 }
Part[ 27] = {   6,  10,  19,  46 }
Part[ 28] = {   4,  26,  40 }
Part[ 29] = {   2,   9,  17,  31,  41,  32 }
Part[ 30] = {  24,  25,  37,  39 }
Part[ 31] = {  12,  16,  38 }
Part[ 32] = {   4,  26,  40,  42 }
Part[ 33] = {   2,   9,  31,  41 }
Part[ 34] = {   1,  43,  44 }
Part[ 35] = {   5,  18,  23,  34 }
Part[ 36] = {  24,  25,  37,  39 }
Part[ 37] = {  12,  16,  38 }
Part[ 38] = {   5,  18,  23,  34,  32 }
Part[ 39] = {   9,   5,  18,  23,  34 }
Part[ 40] = {   5,  18,  23,  34 }
Part[ 41] = {   3,  20,  28,  30,  33 }
Part[ 42] = {  15,  22,  29,  35 }
Part[ 43] = {   3,  20,  28,  30,  33 }
Part[ 44] = {   8,  21 }
Part[ 45] = {  33,  15,  22,  29,  35 }
Part[ 46] = {  14,  12,  16,  38 }
Part[ 47] = {   2,   9,  17,  31,  41 }
Part[ 48] = {   3,  20,  28,  30,  33 }
Part[ 49] = {   1,  43,  44 }
Part[ 50] = {  31,   5,  18,  23,  34 }
Part[ 51] = {  11,  13,  27,  45 }
Part[ 52] = {  21 }
Part[ 53] = {  12,  16,  38 }
Part[ 54] = {   4,  26,  40,  42,  18,  14 }
Part[ 55] = {   6,  10,  14,  19,  46 }
Part[ 56] = {  12,  16,  38 }
Part[ 57] = {  24,  25,  37,  39 }
Part[ 58] = {   7,  32,  36 }
Part[ 59] = {   8,  21 }
Part[ 60] = {   6,  10,  14,  19,  46 }
```

```
Part[  61] = {   15,   22,   29,   35 }
Part[  62] = {    7,   32,   36 }
Part[  63] = {   24,   25,   37,   39 }
Part[  64] = {    4,   26,   40,   42 }
Part[  65] = {    6,   10,   14,   19,   46 }
Part[  66] = {    3,   20,   28,   30,   33 }
Part[  67] = {    4,   26,   40,   42 }
Part[  68] = {    4,   26,   40,   42,   27 }
Part[  69] = {    6,   10,   14,   19,   46 }
Part[  70] = {   12,   16 }
Part[  71] = {    5,   18,   23,   34 }
Part[  72] = {   12,   16,   38 }
Part[  73] = {    4,   26,   40,   42 }
Part[  74] = {    5,   18,   23,   34 }
Part[  75] = {   33,    8,   21 }
Part[  76] = {    7,   32,   36 }
Part[  77] = {   18,    8,   21 }
Part[  78] = {   11,   12,   16,   38 }
Part[  79] = {   11,   13,   27,   45 }
Part[  80] = {    3,   20,   28,   30,   33 }
Part[  81] = {    1,   43,   44 }
Part[  82] = {   11,   13,   27,   45 }
Part[  83] = {    1,   43,   44 }
Part[  84] = {   24,   25,   37,   39 }
Part[  85] = {    3,   20,   28,   30,   33,   39 }
Part[  86] = {    5,   18,   23,   34 }
Part[  87] = {    5,   18,   23,   34 }
Part[  88] = {   24,   37,   39 }
Part[  89] = {    5,   18,   23,   34,   16 }
Part[  90] = {    7,   32,   36 }
Part[  91] = {    3,   20,   28,   30,   33 }
Part[  92] = {    2,    9,   17,   31,   41 }
Part[  93] = {   11,   13,   27,   45 }
Part[  94] = {   20,   24,   25,   37,   39 }
Part[  95] = {   11,   13,   27,   45 }
Part[  96] = {    2,    9,   17,   31,   41 }
Part[  97] = {   11,   13,   27,   45 }
Part[  98] = {    2,    9,   17,   31,   41 }
Part[  99] = {    3,   20,   28,   30,   33 }
Part[ 100] = {    9,    4,   26,   40,   42 }
================================================================
```

< Block Diagonal Solution Matrix >
```
              < Locations >
              00000000000000000000000000000000000000000000000
              00000000011111111112222222222333333333344444444
              12345678901234567890123456789012345678901234556
              < Machines >
              00000000000000000000000000000000000000000000000
              02440123022331124122303322330111404402113000134
< Parts >     46025834308031375529572645796049613481268209711
===========   ***********************************************
(    1)    2  *1111                                          *
(    2)   10  *1111                                          *
(    3)   20  *1111                                          *
(    4)   22  *1111                                          *
(    5)   23  *1111                                          *
(    6)   24  *1111                                1         *
(    7)   28  *111                                           *
(    8)   32  *1111                                          *
(    9)   54  *1111 1                          1             *
(   10)   64  *1111                                          *
(   11)   67  *1111                                          *
(   12)   68  *1111             1                            *
```

```
(   13)   73   *1111                                                          *
(   14)  100   *1111                                              1           *
==========   *=================================================================*
(   15)    8   *     1111                                                      *
(   16)    9   *     1111                                         1           *
(   17)   35   *     1111                                                      *
(   18)   38   *     1111                        1                            *
(   19)   39   *     1111                                         1           *
(   20)   40   *     1111                                                      *
(   21)   50   *     1111                                              1      *
(   22)   71   *     1111                                                      *
(   23)   74   *     1111                                                      *
(   24)   86   *     1111                                                      *
(   25)   87   *     1111                                                      *
(   26)   89   *     1111                                    1                *
==========   *=================================================================*
(   27)   12   *         11111                                   1           *
(   28)   41   *         11111                                                *
(   29)   43   *         11111                                                *
(   30)   48   *         11111                                                *
(   31)   66   *         11111                                                *
(   32)   80   *         11111                                                *
(   33)   85   *         11111                  1                            *
(   34)   91   *         11111                                                *
(   35)   99   *         11111                                                *
==========   *=================================================================*
(   36)   13   *             1111                                            *
(   37)   51   *             1111                                            *
(   38)   79   *             1111                                            *
(   39)   82   *             1111                                            *
(   40)   93   *             1111                                            *
(   41)   95   *             1111                                            *
(   42)   97   *             1111                                            *
==========   *=================================================================*
(   43)    6   *                 1111     1                                  *
(   44)   17   *                 1111                                        *
(   45)   19   *                 1111                                        *
(   46)   21   *         1       1111                                        *
(   47)   42   *                 1111                                        *
(   48)   45   *             1   1111                                        *
(   49)   61   *                 1111                                        *
==========   *=================================================================*
(   50)    3   *                     111                            1        *
(   51)   58   *                     111                                     *
(   52)   62   *                     111                                     *
(   53)   76   *                     111                                     *
(   54)   90   *                     111                                     *
==========   *=================================================================*
(   55)   11   *                         1111                                *
(   56)   30   *                         1111                                *
(   57)   36   *                         1111                                *
(   58)   57   *                         1111                                *
(   59)   63   *                         1111                                *
(   60)   84   *                         1111                                *
(   61)   88   *                         1 11                                *
(   62)   94   *             1           1111                                *
==========   *=================================================================*
(   63)    5   *                             11111                           *
(   64)    7   *             1               11111                           *
(   65)   14   *                             111111                          *
(   66)   16   *                             11111                           *
(   67)   18   *                             11111                           *
(   68)   25   *                             111111                          *
(   69)   27   *                             11  11                          *
```

```
(  70)   55   *                               11111                    *
(  71)   60   *                               11111                    *
(  72)   65   *                               11111                    *
(  73)   69   *                               11111                    *
==========   *===========================================*
(  74)   34   *                                        111            *
(  75)   49   *                                        111            *
(  76)   81   *                                        111            *
(  77)   83   *                                        111            *
==========   *===========================================*
(  78)    1   *                    1                  11             *
(  79)   44   *                                       11             *
(  80)   52   *                                        1             *
(  81)   59   *                                       11             *
(  82)   75   *                 1                     11             *
(  83)   77   *            1                          11             *
==========   *===========================================*
(  84)   31   *                                        111            *
(  85)   37   *                                        111            *
(  86)   46   *                          1             111            *
(  87)   53   *                                        111            *
(  88)   56   *                                        111            *
(  89)   70   *                                         11            *
(  90)   72   *                                        111            *
(  91)   78   *                 1                      111            *
==========   *===========================================*
(  92)    4   *                 1                      11111*
(  93)   15   *            1                           11111*
(  94)   26   *              1                         11111*
(  95)   29   *                      1                 11111*
(  96)   33   *                                        11 11*
(  97)   47   *                                        11111*
(  98)   92   *                                        11111*
(  99)   96   *                                        11111*
( 100)   98   *                                        11111*
==========   ********************************************
```

< Machine cells and Part families >
==
Machine Cell[1] = { 4, 26, 40, 42 }
Machine Cell[2] = { 5, 18, 23, 34 }
Machine Cell[3] = { 3, 20, 28, 30, 33 }
Machine Cell[4] = { 11, 13, 27, 45 }
Machine Cell[5] = { 15, 22, 29, 35 }
Machine Cell[6] = { 7, 32, 36 }
Machine Cell[7] = { 24, 25, 37, 39 }
Machine Cell[8] = { 6, 10, 14, 19, 46 }
Machine Cell[9] = { 1, 43, 44 }
Machine Cell[10] = { 8, 21 }
Machine Cell[11] = { 12, 16, 38 }
Machine Cell[12] = { 2, 9, 17, 31, 41 }
==
Part Family[1] = { 2, 10, 20, 22, 23, 24, 28, 32, 54, 64, 67, 68, 73,
100 }
Part Family[2] = { 8, 9, 35, 38, 39, 40, 50, 71, 74, 86, 87, 89 }
Part Family[3] = { 12, 41, 43, 48, 66, 80, 85, 91, 99 }
Part Family[4] = { 13, 51, 79, 82, 93, 95, 97 }
Part Family[5] = { 6, 17, 19, 21, 42, 45, 61 }
Part Family[6] = { 3, 58, 62, 76, 90 }
Part Family[7] = { 11, 30, 36, 57, 63, 84, 88, 94 }
Part Family[8] = { 5, 7, 14, 16, 18, 25, 27, 55, 60, 65, 69 }
Part Family[9] = { 34, 49, 81, 83 }
Part Family[10] = { 1, 44, 52, 59, 75, 77 }
Part Family[11] = { 31, 37, 46, 53, 56, 70, 72, 78 }

```
Part  Family[12] = { 4, 15, 26, 29, 33, 47, 92, 96, 98 }
================================================================

< Summary of the performance measures >
================================================================
No. of machines                            = 46
No. of part types                          = 100
No. of cells                               = 12
Machine cell size                          = 5
Total no. of 1's in the original MPIM : |A| = 423
Matrix density                             = 0.092
Total no. of within-block 1's              = 394
No. of exceptional elements (EEs)          = 29
No. of voids                               = 6
Sum of EEs and voids                       = 35
Group Cability Index (GCI)                 = 93.14 %
grouping efficiency (GE)                   = 98.90 %
Grouping efficacy (GF)                     = 91.84 %
Machine utilization (MU)                   = 98.50 %
No. of redundant machines (RMs)            = 0
================================================================
```

```
Problem(120) --> Data file name :
DD_05_ZolfaghariLiang(1997)_50x150.cfp

< Machines visited by parts: Process route numbers(PRN) >
===========================================================
Part[   1] = {   7,  14,  23,  34 }
Part[   2] = {   3,   9,  12,  25,  38,  40,  41,  42,  49 }
Part[   3] = {   4,   8,  13,  16,  22,  29,  37,  44,  48 }
Part[   4] = {   4,   8,  13,  22,  37,  44,  46,  48,  50 }
Part[   5] = {   8,  13,  16,  22,  33,  37,  44,  46,  48 }
Part[   6] = {   6,  14,  23,  34,  39 }
Part[   7] = {   5,  18,  35,  50 }
Part[   8] = {   3,  21,  26,  28,  40,  49 }
Part[   9] = {  10,  11,  12,  15,  20 }
Part[  10] = {   6,  23,  39 }
Part[  11] = {   5,  18,  35 }
Part[  12] = {   4,   8,  13,  16,  22,  31,  33,  37,  44,  46,  50 }
Part[  13] = {  10,  11,  12,  15,  20,  30,  32 }
Part[  14] = {  12,  17,  32,  43 }
Part[  15] = {   3,   9,  21,  25,  26,  38,  40,  41,  42 }
Part[  16] = {  11,  12,  15,  30,  32,  43 }
Part[  17] = {   6,   7,  14,  21,  30,  34,  39 }
Part[  18] = {   6,  34,  39 }
Part[  19] = {   4,  16,  31,  33,  37,  44,  46 }
Part[  20] = {   2,   6,  14,  23,  34,  39 }
Part[  21] = {   8,  14,  16,  29,  31,  33,  37,  44,  46,  48,  50 }
Part[  22] = {   8,  24,  29,  31,  33,  37,  46,  48,  50 }
Part[  23] = {   3,  21,  25,  26,  28,  38,  41,  42,  49 }
Part[  24] = {   9,  12,  25,  38,  41,  42,  49 }
Part[  25] = {  10,  11,  12,  15,  20,  30,  32,  43 }
Part[  26] = {   3,   9,  25,  38,  40,  41,  49,  50 }
Part[  27] = {   4,   8,  13,  31,  33,  44,  48,  50 }
Part[  28] = {  11,  15,  43 }
Part[  29] = {   6,  23 }
Part[  30] = {   1,   5,  35 }
Part[  31] = {   3,   9,  25,  26,  28,  38,  40,  41 }
Part[  32] = {   3,  21,  25,  26,  28,  40,  49 }
Part[  33] = {   4,   8,  13,  16,  22,  29,  30,  33,  37,  44,  48,  50
}
Part[  34] = {   1,   5,  18,  49 }
Part[  35] = {  25,  41,  49 }
Part[  36] = {  10,  15,  20,  30 }
Part[  37] = {   6,  23,  30 }
Part[  38] = {   1,   5,  18 }
Part[  39] = {  17,  19,  27 }
Part[  40] = {   3,   9,  21,  25,  26,  28,  40 }
Part[  41] = {   5,  18 }
Part[  42] = {   2,  16,  19,  27,  30,  45,  47 }
Part[  43] = {   4,   8,  13,  16,  22,  31,  33,  37,  44,  46,  48 }
Part[  44] = {   6,   7,  14,  23,  39 }
Part[  45] = {  13,  31,  33,  34,  37,  44 }
Part[  46] = {   2,  19,  30,  36,  43,  45,  47 }
Part[  47] = {   6,   7,  23,  34,  39 }
Part[  48] = {   6,  14,  23 }
Part[  49] = {   6,   7,  14,  23,  34,  50 }
Part[  50] = {   6,   7,  14,  23,  39 }
Part[  51] = {   2,  24,  27,  30,  36,  39,  45,  47 }
Part[  52] = {   2,  17,  19,  24,  27,  30,  36,  47 }
Part[  53] = {  19,  30,  45,  47,  50 }
Part[  54] = {  10,  20,  32,  43 }
Part[  55] = {   6,   7,  30,  39 }
Part[  56] = {  13,  16,  22,  29,  31,  33,  37,  48 }
Part[  57] = {  30,  45,  47 }
Part[  58] = {   2,  38,  45 }
```

```
Part[  59] = {    2,   17,   19,   24,   27,   36,   45 }
Part[  60] = {    1,   35 }
Part[  61] = {    1,    2,   18,   35 }
Part[  62] = {   17,   19,   36,   47,   50 }
Part[  63] = {    2,   19,   24,   27,   30,   45,   47 }
Part[  64] = {    4,   22,   29,   33,   37,   46,   48,   50 }
Part[  65] = {    1,    5,   18,   23 }
Part[  66] = {   18,   35 }
Part[  67] = {    7,   14,   34,   39 }
Part[  68] = {    6,   14,   23,   39 }
Part[  69] = {    2,    4,   17,   19,   24,   30 }
Part[  70] = {   10,   12,   15,   32 }
Part[  71] = {    1,    5 }
Part[  72] = {    1,   18 }
Part[  73] = {   17,   19,   24,   27,   30,   36 }
Part[  74] = {    1,    5,   15,   35,   50 }
Part[  75] = {   22,   29,   31,   33,   37,   46 }
Part[  76] = {   17,   24,   27,   47 }
Part[  77] = {    8,   16,   22,   29,   31,   33,   37,   44,   46,   48,   50 }
Part[  78] = {    2,   17,   19,   24,   27,   36,   45,   47 }
Part[  79] = {    6,    7,   14,   34,   50 }
Part[  80] = {   10,   15,   20,   32,   43 }
Part[  81] = {   17,   19,   24,   27,   36,   45,   47 }
Part[  82] = {    6,    7,   14,   23,   32,   34,   39 }
Part[  83] = {    3,   25,   26,   38,   40,   41,   49 }
Part[  84] = {   10,   11,   12,   15,   20,   32,   43 }
Part[  85] = {    2,   17,   19,   27,   30,   36,   45,   47,   50 }
Part[  86] = {   13,   22,   29,   31,   33,   37,   44,   46,   50 }
Part[  87] = {    9,   21,   25,   26,   41 }
Part[  88] = {   17,   19,   24,   27,   30 }
Part[  89] = {   24,   30,   36,   45,   47 }
Part[  90] = {    6,    7,   39 }
Part[  91] = {    3,    9,   21,   26,   28,   30,   38,   40,   41,   42,   49 }
Part[  92] = {    3,   21,   25,   26,   38,   40,   42,   50 }
Part[  93] = {    5,   18 }
Part[  94] = {   15,   20,   25,   30,   32 }
Part[  95] = {    6,   34 }
Part[  96] = {    7,   14,   23,   34,   35,   39,   50 }
Part[  97] = {    8,   16,   22,   29,   31,   33,   37,   44,   46,   48 }
Part[  98] = {    3,    9,   21,   25,   30,   38,   40,   41,   49,   50 }
Part[  99] = {    4,    8,   16,   22,   29,   37,   44,   46 }
Part[ 100] = {   18 }
Part[ 101] = {   34,   39 }
Part[ 102] = {    1,    5,   18,   35 }
Part[ 103] = {   10,   11,   43 }
Part[ 104] = {    4,   17,   19,   27,   45 }
Part[ 105] = {    1,   18,   35,   50 }
Part[ 106] = {    2,   17,   24,   27,   30,   36,   45,   47 }
Part[ 107] = {   10,   11,   12,   15,   20,   32,   43,   50 }
Part[ 108] = {    2,   17,   19,   24,   27,   30,   36,   47 }
Part[ 109] = {   13,   16,   22,   37,   46,   48,   50 }
Part[ 110] = {   11,   43 }
Part[ 111] = {    6,    7,   14,   23,   34,   39 }
Part[ 112] = {    2,   17,   24,   27,   30,   36,   45,   47 }
Part[ 113] = {    4,    8,   22,   29,   30,   31,   33,   37,   41,   44 }
Part[ 114] = {    7,   14 }
Part[ 115] = {    1,    5,   18,   35 }
Part[ 116] = {   13,   22,   29,   33,   37,   44,   48 }
Part[ 117] = {    2,   17,   19,   27,   30,   45 }
Part[ 118] = {   12,   15,   20,   32,   43 }
Part[ 119] = {    5,   11,   12,   20,   30,   32 }
Part[ 120] = {    7,   14,   23 }
Part[ 121] = {    8,   13,   16,   22,   29,   36,   37,   46,   48,   50 }
Part[ 122] = {    2,   17,   19,   24,   36,   41,   45,   47 }
```

```
Part[ 123] = {   2,  19,  27,  30,  45 }
Part[ 124] = {  24,  27,  36,  45 }
Part[ 125] = {   6,   7,  14,  34,  39 }
Part[ 126] = {   1,  18,  35 }
Part[ 127] = {   1,   5,  18,  50 }
Part[ 128] = {   1,   5,  18 }
Part[ 129] = {   4,  13,  16,  22,  29,  33,  46,  48 }
Part[ 130] = {  17,  19,  24,  30,  36,  45,  47 }
Part[ 131] = {   2,  17,  19,  24,  27,  36,  45 }
Part[ 132] = {   4,   8,  13,  16,  22,  29,  31,  33,  46,  48 }
Part[ 133] = {   1,  35 }
Part[ 134] = {  18 }
Part[ 135] = {  13,  16,  22,  29,  31,  37,  46,  48 }
Part[ 136] = {   1,  18,  35 }
Part[ 137] = {   5,  18,  30,  35,  50 }
Part[ 138] = {  13,  22,  29,  31,  44,  46,  48,  50 }
Part[ 139] = {   1,  17,  19,  27,  36,  45,  47 }
Part[ 140] = {  17,  19,  24,  27,  30,  36,  45 }
Part[ 141] = {  19,  27,  30,  36,  46,  47 }
Part[ 142] = {   4,   8,  16,  31,  37,  44,  46,  48,  50 }
Part[ 143] = {  19,  27,  30,  36,  45,  47 }
Part[ 144] = {  29,  37,  46,  48,  50 }
Part[ 145] = {  10,  11,  12,  20,  43 }
Part[ 146] = {   6,  14,  23,  39,  50 }
Part[ 147] = {   4,   8,  13,  15,  16,  22,  33,  44,  50 }
Part[ 148] = {   5,   8,  29,  31,  33,  37,  46,  50 }
Part[ 149] = {  35,  40 }
Part[ 150] = {   8,  13,  16,  22,  29,  31,  37,  44,  46 }
==================================================================
```

< Block Diagonal Solution Matrix >
```
          < Locations >
          000000000000000000000000000000000000000000000000000
          00000000011111111112222222222333333333344444444445
          12345678901234567890123456789012345678901234567890
          < Machines >
          000000000000000000000000000000000000000000000000000
          00130112233440011223334445002223444411112340012 33
< Parts >   15852794706574836291374680391568801290125023674349
==========  ***************************************************
(    1)    7  * 111                        1                    *
(    2)   11  * 111                                             *
(    3)   30  *11 1                                             *
(    4)   34  *111                              1               *
(    5)   38  *111                                              *
(    6)   41  * 11                                              *
(    7)   60  *1  1                                             *
(    8)   61  *1 111                                            *
(    9)   65  *111                                      1   *
(   10)   66  *   11                                            *
(   11)   71  *11                                              *
(   12)   72  *1 1                                              *
(   13)   74  *11 1                    1                1       *
(   14)   93  * 11                                             *
(   15)  100  *   1                                            *
(   16)  102  *1111                                            *
(   17)  105  *1 11                     1                      *
(   18)  115  *1111                                            *
(   19)  126  *1 11                                            *
(   20)  127  *111                      1                      *
(   21)  128  *111                                             *
(   22)  133  *1  1                                            *
(   23)  134  *   1                                            *
(   24)  136  *1 11                                            *
```

```
(   25)  137  * 111        1                        1                          *
(   26)  149  *    1                                         1                 *
==========  *================================================================*
(   27)   39  *         11  1                                                  *
(   28)   42  *      1 1 11  11     1                                          *
(   29)   46  *      1 1   1111                                  1             *
(   30)   51  *      1  111111                                              1*
(   31)   52  *     1111111 1                                                  *
(   32)   53  *        1   1 11              1                                 *
(   33)   57  *            1 11                                                *
(   34)   58  *      1         1                     1                         *
(   35)   59  *     11111  11                                                  *
(   36)   62  *        11   1 1              1                                 *
(   37)   63  *      1 1111  11                                                *
(   38)   69  *     1111  1    1                                              *
(   39)   73  *       111111                                                  *
(   40)   76  *        1 11    1                                              *
(   41)   78  *     11111  111                                                *
(   42)   81  *      1111  111                                                *
(   43)   85  *     111 11111              1                                  *
(   44)   88  *       11111                                                   *
(   45)   89  *        1 1111                                                 *
(   46)  104  *        11  1   1 1                                            *
(   47)  106  *      11 111111                                                *
(   48)  108  *      1111111 1                                                *
(   49)  112  *      11 111111                                                *
(   50)  117  *      111 11 1                                                 *
(   51)  122  *      1111  111                      1                         *
(   52)  123  *      1 1 11  1                                                *
(   53)  124  *          11 11                                               *
(   54)  130  *       111 1111                                               *
(   55)  131  *      11111  11                                               *
(   56)  139  *1      11 1 111                                               *
(   57)  140  *      1111111                                                 *
(   58)  141  *       1 111  1              1                                *
(   59)  143  *       1 11111                                                *
==========  *================================================================*
(   60)    3  *              1111111   11 1                                  *
(   61)    4  *              111 1     11111                                 *
(   62)    5  *               1111   11111                                   *
(   63)   12  *              11111 11111 1                                    *
(   64)   19  *              1   1  11111                                     *
(   65)   21  *               1 1 11111111                           1       *
(   66)   22  *          1      1    1111  111                               *
(   67)   27  *              111    11 1 11                                  *
(   68)   33  *          1   111111 111 11                                   *
(   69)   43  *              11111 111111                                    *
(   70)   45  *               1     1111                               1 *
(   71)   56  *              1111111  1                                      *
(   72)   64  *          1    11 11 111                                      *
(   73)   75  *               11111 1                                        *
(   74)   77  *             1 1111111111                                     *
(   75)   86  *              1 1111111 1                                     *
(   76)   97  *              1 111111111                                     *
(   77)   99  *             11 111   111                                     *
(   78)  109  *              111    1 111                                    *
(   79)  113  *          1    11  111111             1                       *
(   80)  116  *               1 11 111 1                                     *
(   81)  121  *           1     11111   1 111                                *
(   82)  129  *              1 1111 1   11                                   *
(   83)  132  *              11111111   11                                   *
(   84)  135  *               11111 1 11                                     *
(   85)  138  *               1 111   1111                                   *
(   86)  142  *              11 1   1 11111                                  *
```

```
(  87) 144  *                      1   1 111                          *
(  88) 147  *                   11111  1 1  1                    1     *
(  89) 148  * 1                   1   1111 1 1                         *
(  90) 150  *                   111111 111                            *
==========  *=========================================================*
(  91)   2  *                               11 1   11111   1          *
(  92)   8  *                               1 1 11 1   1              *
(  93)  15  *                               11111 1111                *
(  94)  23  *                               1 11111 111               *
(  95)  24  *                                1 1   1 111   1          *
(  96)  26  *                               111 1   111 1             *
(  97)  31  *                               11 111111                 *
(  98)  32  *                               1 1111 1   1              *
(  99)  35  *                                1      1 1              *
( 100)  40  *                               111111 1                  *
( 101)  83  *                               1  11 111 1               *
( 102)  87  *                                1111   1                 *
( 103)  91  *              1                111 1111111                *
( 104)  92  *                               11 111 11 1               *
( 105)  98  *              1                11111  111 1              *
==========  *=========================================================*
( 106)   9  *                                        11111            *
( 107)  13  *                1                       111111            *
( 108)  14  *          1                              1   11           *
( 109)  16  *                1                        111 11           *
( 110)  25  *                1                       1111111           *
( 111)  28  *                                         1 1  1           *
( 112)  36  *                1                        1   11           *
( 113)  54  *                                         1    111         *
( 114)  70  *                                         1 11 1           *
( 115)  80  *                                         1   1111         *
( 116)  84  *                                         1111111          *
( 117)  94  *                1                 1        111            *
( 118) 103  *                                         11   1           *
( 119) 107  *                           1             1111111          *
( 120) 110  *                                         1    1           *
( 121) 118  *                                          11111           *
( 122) 119  * 1              1                         11 11           *
( 123) 145  *                                        111 1 1          *
==========  *=========================================================*
( 124)   1  *                                            1111 *
( 125)   6  *                                          1 1111*
( 126)  10  *                                          1  1 1*
( 127)  17  *                1                  1      111 11*
( 128)  18  *                                          1   11*
( 129)  20  *           1                              1 1111*
( 130)  29  *                                          1  1  *
( 131)  37  *                1                         1  1  *
( 132)  44  *                                         1111 1*
( 133)  47  *                                         11 111*
( 134)  48  *                                          1 11  *
( 135)  49  *                                  1       11111 *
( 136)  50  *                                          1111 1*
( 137)  55  *                1                         11   1*
( 138)  67  *                                           11 11*
( 139)  68  *                                          1 11 1*
( 140)  79  *                                  1       111 1 *
( 141)  82  *                                        1 1111111*
( 142)  90  *                                          11   1*
( 143)  95  *                                          1    1 *
( 144)  96  *        1                         1        11111*
( 145) 101  *                                             11*
( 146) 111  *                                         1111111*
( 147) 114  *                                           11   *
```

```
( 148) 120  *                                                    111  *
( 149) 125  *                                                    111 11*
( 150) 146  *                             1                      1 11 1*
=========== ****************************************************

< Machine cells and Part families  >
=============================================================
Machine Cell[ 1] = { 1, 5, 18, 35 }
Machine Cell[ 2] = { 2, 17, 19, 24, 27, 30, 36, 45, 47 }
Machine Cell[ 3] = { 4, 8, 13, 16, 22, 29, 31, 33, 37, 44, 46, 48, 50 }
Machine Cell[ 4] = { 3, 9, 21, 25, 26, 28, 38, 40, 41, 42, 49 }
Machine Cell[ 5] = { 10, 11, 12, 15, 20, 32, 43 }
Machine Cell[ 6] = { 6, 7, 14, 23, 34, 39 }
=============================================================
Part  Family[ 1] = { 7, 11, 30, 34, 38, 41, 60, 61, 65, 66, 71, 72, 74,
93, 100, 102, 105, 115, 126, 127, 128, 133, 134, 136, 137, 149 }
Part  Family[ 2] = { 39, 42, 46, 51, 52, 53, 57, 58, 59, 62, 63, 69, 73,
76, 78, 81, 85, 88, 89, 104, 106, 108, 112, 117, 122, 123, 124, 130, 131,
139, 140, 141, 143 }
Part  Family[ 3] = { 3, 4, 5, 12, 19, 21, 22, 27, 33, 43, 45, 56, 64, 75,
77, 86, 97, 99, 109, 113, 116, 121, 129, 132, 135, 138, 142, 144, 147,
148, 150 }
Part  Family[ 4] = { 2, 8, 15, 23, 24, 26, 31, 32, 35, 40, 83, 87, 91, 92,
98 }
Part  Family[ 5] = { 9, 13, 14, 16, 25, 28, 36, 54, 70, 80, 84, 94, 103,
107, 110, 118, 119, 145 }
Part  Family[ 6] = { 1, 6, 10, 17, 18, 20, 29, 37, 44, 47, 48, 49, 50, 55,
67, 68, 79, 82, 90, 95, 96, 101, 111, 114, 120, 125, 146 }
=============================================================

< Summary of the performance measures >
=============================================================
No. of machines                          = 50
No. of part types                        = 150
No. of cells                             = 6
Machine cell size                        = 13
Total no. of 1's in the original MPIM : |A| = 874
Matrix density                           = 0.117
Total no. of within-block 1's            = 814
No. of exceptional elements (EEs)        = 60
No. of voids                             = 443
Sum of EEs and voids                     = 503
Group Cability Index (GCI)               = 93.14 %
grouping efficiency (GE)                 = 81.90 %
Grouping efficacy (GF)                   = 61.81 %
Machine utilization (MU)                 = 64.76 %
No. of redundant machines (RMs)          = 0
=============================================================
```

< Machines visited by parts: Process route numbers(PRN) >
==
```
Part[  1] = {  18,  19,  26,  27,  32,  40 }
Part[  2] = {  16,  23,  34,  35,  41 }
Part[  3] = {   7,  14,  15,  24,  30,  37,  40,  43,  45 }
Part[  4] = {   7,  13,  15,  20,  24,  30,  40,  45 }
Part[  5] = {   7,  13,  15,  24,  30,  37,  38,  40,  43 }
Part[  6] = {   9,  10,  14,  25,  44 }
Part[  7] = {   7,  13,  14,  20,  30,  37,  40,  43 }
Part[  8] = {  21,  22,  29,  31,  40 }
Part[  9] = {   7,  13,  15,  18,  20,  24,  40,  45 }
Part[ 10] = {   9,  14,  17,  25,  39,  44 }
Part[ 11] = {   2,   3,   5,  16,  23,  34,  35,  41 }
Part[ 12] = {   1,  33,  36,  37,  38,  39,  40,  41,  46 }
Part[ 13] = {  33,  38,  39,  40,  46 }
Part[ 14] = {  10,  14,  17,  44 }
Part[ 15] = {   4,  21,  27,  28,  29,  31 }
Part[ 16] = {   2,  25,  36,  38,  39,  46 }
Part[ 17] = {  19,  26,  27,  32 }
Part[ 18] = {  10,  17,  25,  44 }
Part[ 19] = {  18,  19,  26,  27,  32 }
Part[ 20] = {   9,  10,  14,  17,  25 }
Part[ 21] = {   3,  16,  34,  35 }
Part[ 22] = {   7,  14,  15,  20,  21,  22,  24,  30,  37,  43,  45 }
Part[ 23] = {   5,  14,  23,  34,  35,  41 }
Part[ 24] = {  21,  28,  31 }
Part[ 25] = {  18,  19,  26,  27 }
Part[ 26] = {   7,  13,  15,  20,  24,  30,  40,  45 }
Part[ 27] = {   6,  18,  19,  26,  27,  32 }
Part[ 28] = {  21,  22,  28,  31,  40 }
Part[ 29] = {   5,   8,  15,  16,  23,  34,  35,  41,  43 }
Part[ 30] = {   6,  18,  26,  32 }
Part[ 31] = {  21,  22,  28,  29,  31,  40 }
Part[ 32] = {  21,  22,  28,  29,  31 }
Part[ 33] = {   3,  10,  14,  17,  25,  39,  44 }
Part[ 34] = {  10,  14,  17,  25,  44 }
Part[ 35] = {   6,  18,  19,  26,  27,  32,  39 }
Part[ 36] = {  33,  36,  38,  39 }
Part[ 37] = {   1,   2,   8,  22,  28,  29,  31 }
Part[ 38] = {   1,   2,  33,  36,  38,  39 }
Part[ 39] = {  13,  20,  24,  30,  37,  40,  43 }
Part[ 40] = {  33,  38,  39,  46 }
Part[ 41] = {   7,  15,  21,  22,  24,  30,  37,  40,  43,  45 }
Part[ 42] = {   7,   8,  13,  24,  30,  37,  40,  43,  45 }
Part[ 43] = {   2,  36,  38,  46 }
Part[ 44] = {   6,  18,  19,  26 }
Part[ 45] = {   1,   2,   4,  11 }
Part[ 46] = {   1,   2,   4,  11 }
Part[ 47] = {   1,   2,  25,  33,  36,  39,  46 }
Part[ 48] = {   7,  13,  20,  30,  37,  40,  43,  45 }
Part[ 49] = {   7,  13,  14,  15,  20,  24,  30,  37,  40,  43 }
Part[ 50] = {   9,  10,  20,  25,  44 }
Part[ 51] = {   7,  13,  15,  20,  21,  24,  30,  40,  45 }
Part[ 52] = {  21,  22,  27,  28 }
Part[ 53] = {   5,   8,  11,  12,  30,  42 }
Part[ 54] = {  33,  36,  38,  39,  46 }
Part[ 55] = {   9,  14,  17,  25 }
Part[ 56] = {   3,   5,  16,  19,  26,  34,  35 }
Part[ 57] = {  21,  22,  28,  29 }
Part[ 58] = {   3,   5,  14,  16,  35,  41 }
Part[ 59] = {   3,   5,  16,  23,  34,  35 }
Part[ 60] = {   7,  13,  15,  20,  30,  37,  43,  45 }
```

```
Part[  61] = {   21,   29,   31 }
Part[  62] = {   18,   19,   26 }
Part[  63] = {   21,   22,   28,   29,   31 }
Part[  64] = {   10,   17,   25,   35,   38,   40,   44,   46 }
Part[  65] = {   12,   20,   24,   30,   40,   45 }
Part[  66] = {    2,    3,    5,    9,   10,   17,   23,   34,   41,   44 }
Part[  67] = {   15,   18,   19,   21,   26 }
Part[  68] = {    9,   10,   14,   17,   25 }
Part[  69] = {   21,   27,   28,   29,   31 }
Part[  70] = {   21,   22,   28,   29,   40 }
Part[  71] = {    6,   18,   19,   27,   39 }
Part[  72] = {    1,    2,    4,    8,   11 }
Part[  73] = {   10,   14,   17,   20,   25,   43,   44 }
Part[  74] = {    1,    2,    4,   11,   12,   35,   42 }
Part[  75] = {    1,    3,    4,   16,   23,   35,   41,   43 }
Part[  76] = {    4,    7,   13,   14,   15,   20,   30,   37,   43,   45 }
Part[  77] = {    1,   33,   36,   37,   38,   39,   40,   41 }
Part[  78] = {    1,    8,   11,   12,   24,   41,   42 }
Part[  79] = {    6,   18,   26,   27,   32 }
Part[  80] = {   33,   36,   38,   39 }
Part[  81] = {   33,   36,   38,   46 }
Part[  82] = {    6,   26,   27,   32,   35 }
Part[  83] = {    3,    4,    5,   16,   34,   41 }
Part[  84] = {   22,   28,   29,   31 }
Part[  85] = {    2,   13,   15,   20,   24,   30,   34,   37,   40,   43,   45 }
Part[  86] = {    9,   10,   14,   25,   38,   44,   46 }
Part[  87] = {    7,   13,   14,   20,   24,   30,   37,   43,   45 }
Part[  88] = {   33,   36,   38,   46 }
Part[  89] = {    6,   18,   26,   32,   45 }
Part[  90] = {    5,   16,   23,   34,   35,   41 }
Part[  91] = {    6,   15,   18,   19,   26,   27,   32 }
Part[  92] = {    5,    7,   13,   15,   16,   20,   24,   30,   37,   40,   43 }
Part[  93] = {   21,   22,   28,   29 }
Part[  94] = {   36,   39,   46 }
Part[  95] = {    9,   10,   17,   25,   44 }
Part[  96] = {    7,   12,   13,   15,   24,   30,   37,   40,   43 }
Part[  97] = {   36,   38,   39,   46 }
Part[  98] = {    9,   10,   17,   25,   44 }
Part[  99] = {    1,    2,    8,   11,   12,   42 }
Part[ 100] = {   12,   13,   15,   20,   24,   30,   37,   43,   45 }
Part[ 101] = {    9,   14,   17,   20,   25,   43,   44 }
Part[ 102] = {    9,   10,   14,   17,   25,   44 }
Part[ 103] = {    3,   14,   16,   19,   23,   34,   35 }
Part[ 104] = {   22,   28,   29,   31,   40 }
Part[ 105] = {   21,   22,   29,   31 }
================================================================

< Block Diagonal Solution Matrix >
            < Locations >
            000000000000000000000000000000000000000000000000
            000000000011111111112222222222333333333344444444
            123456789012345678901234567890123456789012345  6
            < Machines >
            000000000000000000000000000000000000000000000000
            011112401122334440112230012334333342222230000114
< Parts >   904754735040703568967235634513689612891124812  2
==========  ************************************************
(    1)   6 *111 11                                        *
(    2)  10 *1 1111                               1        *
(    3)  14 * 111 1                                        *
(    4)  18 * 1 111                                        *
(    5)  20 *11111                                         *
(    6)  33 * 11111                   1           1        *
(    7)  34 * 11111                                        *
```

```
(    8)   50   *11  11    1                                            *
(    9)   55   *1 111                                                  *
(   10)   64   *  1 111          1                1    1 1             *
(   11)   68   *11111                                                  *
(   12)   73   *  11111     1       1                                  *
(   13)   86   *111 11                                   1 1           *
(   14)   95   *11 111                                                 *
(   15)   98   *11 111                                                 *
(   16)  101   *1 1111     1       1                                   *
(   17)  102   *111111                                                 *
==========    *=================================================*
(   18)    3   *   1    1 1 111111                                     *
(   19)    4   *        111111 1 1                                     *
(   20)    5   *        111 11111                    1                 *
(   21)    7   *   1    11 1 1111                                      *
(   22)    9   *        11111  1 1 1                                   *
(   23)   22   *   1    1 11111 11                       11            *
(   24)   26   *        111111 1 1                                     *
(   25)   39   *         1 111111                                      *
(   26)   41   *        1 1 111111                       11            *
(   27)   42   *        11  111111                            1        *
(   28)   48   *        11 1 11111                                     *
(   29)   49   *   1    111111111                                      *
(   30)   51   *        111111 1 1                  1                  *
(   31)   60   *        1111 11 11                                     *
(   32)   65   *          111 1 1                                 1    *
(   33)   76   *   1    1111 11 11                           1         *
(   34)   85   *        111111111          1             1            *
(   35)   87   *   1    11 1111 11                                     *
(   36)   92   *        111111111       11                            *
(   37)   96   *        111 11111                              1       *
(   38)  100   *        111111 11                              1       *
==========    *=================================================*
(   39)    1   *              1    11111                               *
(   40)   17   *                   1111                                *
(   41)   19   *                   11111                               *
(   42)   25   *                   1111                                *
(   43)   27   *                   111111                              *
(   44)   30   *                   11 1 1                              *
(   45)   35   *                   111111         1                    *
(   46)   44   *                   1111                                *
(   47)   62   *                    111                                *
(   48)   67   *          1         111              1                 *
(   49)   71   *                   111 1           1                   *
(   50)   79   *                   11 111                              *
(   51)   82   *                   1   111      1                      *
(   52)   89   *                   111 1 1                             *
(   53)   91   *          1        111111                              *
==========    *=================================================*
(   54)    2   *                           11111                       *
(   55)   11   *                           1111111              1      *
(   56)   21   *                           1 1 11                      *
(   57)   23   *   1                        1 1111                     *
(   58)   29   *            1       1       111111              1      *
(   59)   56   *                        11  111 11                     *
(   60)   58   *   1                        111  11                    *
(   61)   59   *                           111111                      *
(   62)   66   *11 1 1                     11 11 1            1         *
(   63)   75   *                 1         1 11 11          1 1        *
(   64)   83   *                           111 1 1             1       *
(   65)   90   *                           111111                      *
(   66)  103   *   1                1      1 1111                       *
==========    *=================================================*
(   67)   12   *            11            111111      1                *
```

```
(  68)   13   *              1                  1 111              *
(  69)   16   *        1                         1111        1     *
(  70)   36   *                                  1111              *
(  71)   38   *                                  1111        11    *
(  72)   40   *                                  1 111             *
(  73)   43   *                                   11 1        1    *
(  74)   47   *        1                          11 11       11   *
(  75)   54   *                                   11111            *
(  76)   77   *              11                   11111       1    *
(  77)   80   *                                   1111             *
(  78)   81   *                                   111 1            *
(  79)   88   *                                   111 1            *
(  80)   94   *                                   1 11             *
(  81)   97   *                                   1111             *
==========   *=================================================*
(  82)    8   *              1                    11 11            *
(  83)   15   *                    1            1 111   1          *
(  84)   24   *                                 1 1 1             *
(  85)   28   *              1                  111 1             *
(  86)   31   *              1                  11111             *
(  87)   32   *                                 11111             *
(  88)   37   *                                  111111 1          *
(  89)   52   *                    1            111               *
(  90)   57   *                                 1111              *
(  91)   61   *                                 1  11             *
(  92)   63   *                                 11111             *
(  93)   69   *                    1            1 111             *
(  94)   70   *              1                  1111              *
(  95)   84   *                                 1111              *
(  96)   93   *                                 1111              *
(  97)  104   *              1                   1111             *
(  98)  105   *                                 11 11             *
==========   *=================================================*
(  99)   45   *                                         111 1   *
( 100)   46   *                                         111 1   *
( 101)   53   *          1              1                  1111*
( 102)   72   *                                         11111   *
( 103)   74   *                            1            111 111*
( 104)   78   *          1                 1            1  1111*
( 105)   99   *                                         11 1111*
==========   *************************************************
```

< Machine cells and Part families >
==
Machine Cell[1] = { 9, 10, 14, 17, 25, 44 }
Machine Cell[2] = { 7, 13, 15, 20, 24, 30, 37, 40, 43, 45 }
Machine Cell[3] = { 6, 18, 19, 26, 27, 32 }
Machine Cell[4] = { 3, 5, 16, 23, 34, 35, 41 }
Machine Cell[5] = { 33, 36, 38, 39, 46 }
Machine Cell[6] = { 21, 22, 28, 29, 31 }
Machine Cell[7] = { 1, 2, 4, 8, 11, 12, 42 }
==
Part Family[1] = { 6, 10, 14, 18, 20, 33, 34, 50, 55, 64, 68, 73, 86,
95, 98, 101, 102 }
Part Family[2] = { 3, 4, 5, 7, 9, 22, 26, 39, 41, 42, 48, 49, 51, 60,
65, 76, 85, 87, 92, 96, 100 }
Part Family[3] = { 1, 17, 19, 25, 27, 30, 35, 44, 62, 67, 71, 79, 82,
89, 91 }
Part Family[4] = { 2, 11, 21, 23, 29, 56, 58, 59, 66, 75, 83, 90, 103 }
Part Family[5] = { 12, 13, 16, 36, 38, 40, 43, 47, 54, 77, 80, 81, 88,
94, 97 }
Part Family[6] = { 8, 15, 24, 28, 31, 32, 37, 52, 57, 61, 63, 69, 70,
84, 93, 104, 105 }
Part Family[7] = { 45, 46, 53, 72, 74, 78, 99 }

```
============================================================
< Summary of the performance measures >
============================================================
No. of machines                            = 46
No. of part types                          = 105
No. of cells                               = 7
Machine cell size                          = 10
Total no. of 1's in the original MPIM : |A| = 641
Matrix density                             = 0.133
Total no. of within-block 1's              = 544
No. of exceptional elements (EEs)          = 97
No. of voids                               = 158
Sum of EEs and voids                       = 255
Group Cability Index (GCI)                 = 84.87 %
grouping efficiency (GE)                    = 87.57 %
Grouping efficacy (GF)                      = 68.09 %
Machine utilization (MU)                    = 77.49 %
No. of redundant machines (RMs)            = 0
============================================================
```

```
Problem(122) --> Data file name :
DD_07_NunkaewPhruksaphanrat(2014)_50x150.cfp

< Machines visited by parts: Process route numbers(PRN) >
========================================================
Part[   1] = {  11,  13,  16,  30,  42 }
Part[   2] = {   2,  11,  16,  30,  42 }
Part[   3] = {   2,  11,  13,  16 }
Part[   4] = {   2,  11,  13,  16 }
Part[   5] = {   8,  10,  19,  24,  27,  29 }
Part[   6] = {   1,  30,  35 }
Part[   7] = {  10,  11,  19,  24,  27,  29 }
Part[   8] = {   4,   5,   9,  20,  50 }
Part[   9] = {   1,  30,  35 }
Part[  10] = {   7,  26,  32,  38,  46,  49 }
Part[  11] = {   4,   5,   9,  20,  37,  50 }
Part[  12] = {  24,  27,  28,  29,  44,  46 }
Part[  13] = {   1,  30,  35 }
Part[  14] = {   4,   8,   9,  37,  39,  41 }
Part[  15] = {  14,  33,  36,  45,  47,  50 }
Part[  16] = {  17,  18,  36,  45,  47 }
Part[  17] = {  21,  24,  27,  28,  29 }
Part[  18] = {   3,   7,  12,  26,  40,  46,  49 }
Part[  19] = {   5,   9,  20,  37,  50 }
Part[  20] = {  24,  27,  28,  29 }
Part[  21] = {  23,  34,  48 }
Part[  22] = {   6 }
Part[  23] = {  14,  15,  17,  45,  47 }
Part[  24] = {   1,   2,  11,  13,  35 }
Part[  25] = {  11,  14,  15,  36,  45,  47 }
Part[  26] = {   1,   2,  11,  13,  14,  30,  35,  42 }
Part[  27] = {   3,  12,  26,  32,  38,  40,  46,  49 }
Part[  28] = {   2,  13,  16,  30 }
Part[  29] = {   3,   7,  32,  40,  46 }
Part[  30] = {  40,  46 }
Part[  31] = {   3,   7,  12,  26,  32,  38,  40,  46 }
Part[  32] = {   3,   7,  12,  26,  38,  40,  46,  49 }
Part[  33] = {   3,   7,  12,  26,  38,  40,  46,  49 }
Part[  34] = {   6,  23,  34,  48 }
Part[  35] = {   3,  12,  21,  26,  40,  46,  49 }
Part[  36] = {   7,  26,  38,  40,  49 }
Part[  37] = {   7,  12,  26,  38,  40,  46,  49 }
Part[  38] = {   6,  23,  34,  48 }
Part[  39] = {   1,   3,  11,  13,  15,  30,  45 }
Part[  40] = {   3,   7,  26,  40,  46 }
Part[  41] = {   7,  26,  36,  38,  40 }
Part[  42] = {   6,  34,  42 }
Part[  43] = {   6,  34,  48 }
Part[  44] = {   3,   7,   9,  26,  32,  38,  46,  49 }
Part[  45] = {   3,   7,  26,  32,  38,  46,  49 }
Part[  46] = {  19,  21,  25,  28,  41 }
Part[  47] = {  16,  30 }
Part[  48] = {  19,  21,  28,  41 }
Part[  49] = {  19,  21,  25,  41 }
Part[  50] = {  13,  17,  18,  33,  45,  47 }
Part[  51] = {  19,  25,  41,  44 }
Part[  52] = {  19,  25,  28,  41,  44 }
Part[  53] = {   4,   5,   8,   9,  20,  37 }
Part[  54] = {  23 }
Part[  55] = {   5,   8,   9,  20,  22,  37,  39 }
Part[  56] = {   6,  48 }
Part[  57] = {  23,  34 }
Part[  58] = {   4,   5,   8,  20,  22,  37,  50 }
Part[  59] = {   5,   9,  20,  22,  39 }
```

```
Part[  60] = {  23,  48 }
Part[  61] = {   6,  23,  34 }
Part[  62] = {  23,  48 }
Part[  63] = {   6,  23,  34,  48 }
Part[  64] = {  11,  23,  48 }
Part[  65] = {  20,  23,  34,  48 }
Part[  66] = {  34,  48 }
Part[  67] = {  10,  21,  25,  27,  40,  43,  44 }
Part[  68] = {  21,  25,  27,  31,  43 }
Part[  69] = {   2,  13,  16,  30 }
Part[  70] = {   3,   7,  12,  17,  28,  40,  46,  49 }
Part[  71] = {   5,   8,   9,  20,  22,  37,  39,  50 }
Part[  72] = {  21,  25,  27,  31,  41,  43 }
Part[  73] = {   4,   5,   8,   9,  20,  22 }
Part[  74] = {   4,   5,  20,  22,  39 }
Part[  75] = {   3,   8,  12,  26,  38,  44,  46 }
Part[  76] = {   3,   5,  12,  26,  38,  40,  49 }
Part[  77] = {  21,  25,  26,  27,  31,  43 }
Part[  78] = {   4,   5,  20,  22,  39 }
Part[  79] = {   4,   5,   8,   9,  20,  22,  39 }
Part[  80] = {  34,  48 }
Part[  81] = {   5,   8,   9,  20,  22,  37,  39,  50 }
Part[  82] = {  10,  21,  31,  36,  43,  44 }
Part[  83] = {   5,   9,  20,  22,  36,  39,  50 }
Part[  84] = {   4,   8,  20,  37,  39,  40,  50 }
Part[  85] = {   8,  20,  39,  50 }
Part[  86] = {   4,   8,   9,  12,  20,  22,  37,  50 }
Part[  87] = {   4,   8,   9,  20,  37,  39 }
Part[  88] = {   5,   8,   9,  19,  20,  22,  37 }
Part[  89] = {   5,   8,   9,  18,  22,  37,  39,  50 }
Part[  90] = {   1,  30,  35 }
Part[  91] = {  24,  27,  29,  44 }
Part[  92] = {  34,  48 }
Part[  93] = {   4,   5,   8,   9,  20,  22,  37,  50 }
Part[  94] = {  19,  21,  25,  28,  41 }
Part[  95] = {   2,  16,  30 }
Part[  96] = {   6,  48 }
Part[  97] = {   5,   6 }
Part[  98] = {   2,  13,  25,  42,  45 }
Part[  99] = {   2,  13,  42 }
Part[ 100] = {   2,  16,  30,  35,  42 }
Part[ 101] = {  34,  48 }
Part[ 102] = {  34,  48,  50 }
Part[ 103] = {   6 }
Part[ 104] = {   6,  34 }
Part[ 105] = {   3,   7,  12,  26,  38,  46,  49 }
Part[ 106] = {   3,   7,  12,  26,  38,  40,  46 }
Part[ 107] = {   7,  12,  26,  38,  40,  49 }
Part[ 108] = {   7,  26,  38,  40,  44,  49 }
Part[ 109] = {   3,   7,  12,  32,  40,  46,  49 }
Part[ 110] = {   3,   7,  12,  27,  40,  49 }
Part[ 111] = {   7,  12,  40,  46,  49 }
Part[ 112] = {   7,  26,  32,  38,  49 }
Part[ 113] = {   3,  12,  26,  32,  38,  40,  46,  49 }
Part[ 114] = {   7,  26,  38,  40 }
Part[ 115] = {   6,  22,  34 }
Part[ 116] = {   6,  34 }
Part[ 117] = {   6,  34,  45 }
Part[ 118] = {  19,  21,  24,  25,  27,  28,  29 }
Part[ 119] = {   6 }
Part[ 120] = {  19,  21,  24,  29 }
Part[ 121] = {  34,  48 }
Part[ 122] = {  19,  21,  24,  29 }
Part[ 123] = {  34,  40,  48 }
```

```
Part[ 124] = {   10,   19,   24,   29 }
Part[ 125] = {    6 }
Part[ 126] = {    2,   11,   13,   16,   30,   42 }
Part[ 127] = {    6,   34 }
Part[ 128] = {    1,   11,   13,   35 }
Part[ 129] = {    6,   34 }
Part[ 130] = {    1,    2,    7,   11,   13,   17,   35 }
Part[ 131] = {    6,   34,   48 }
Part[ 132] = {   10,   21,   43,   44 }
Part[ 133] = {    6,   48 }
Part[ 134] = {   10,   24,   27,   31,   41,   43,   44 }
Part[ 135] = {   23 }
Part[ 136] = {   10,   21,   25,   27,   31,   43 }
Part[ 137] = {   23,   48 }
Part[ 138] = {   10,   21,   25,   27,   31,   44,   50 }
Part[ 139] = {   23,   48 }
Part[ 140] = {   23,   48 }
Part[ 141] = {    5,    9,   20,   37,   50 }
Part[ 142] = {    5,    8,    9,   20,   37,   50 }
Part[ 143] = {    4,    8,    9,   20,   37,   39 }
Part[ 144] = {   14,   17,   18,   36,   47 }
Part[ 145] = {   15,   17,   33,   36,   45,   47 }
Part[ 146] = {   14,   15,   17,   18,   33,   36,   45,   47 }
Part[ 147] = {   14,   15,   17,   18,   25,   33,   45,   47 }
Part[ 148] = {   14,   18,   19,   33,   36,   45,   47 }
Part[ 149] = {   14,   15,   17,   18,   33,   36,   41,   45,   47 }
Part[ 150] = {   14,   33,   45,   47 }
================================================================

< Block Diagonal Solution Matrix >
            < Locations >
            0000000000000000000000000000000000000000000000000
            0000000001111111111222222222233333333334444444445
            1234567890123456789012345678901234567890123456789 0
            < Machines >
            0000000000000000000000000000000000000000000000000
            0012334440000223350234001113341111334411222222 3444
< Parts >   3726280694589027906348121360524578365709145789 1134
=========== *************************************************
(    1)  10 * 1 111 11                                       *
(    2)  18 *1111   111                                      *
(    3)  27 *1 1111111                                       *
(    4)  29 *11  1 11                                        *
(    5)  30 *       11                                       *
(    6)  31 *11111111                                        *
(    7)  32 *1111 1111                                       *
(    8)  33 *1111 1111                                       *
(    9)  35 *1 11  111                          1            *
(   10)  36 * 1 1 11 1                                       *
(   11)  37 * 111 1111                                       *
(   12)  40 *11 1  11                                        *
(   13)  41 * 1 1 11                     1                   *
(   14)  44 *11 111 11    1                                  *
(   15)  45 *11 111 11                                       *
(   16)  70 *111   111                 1           1        *
(   17)  75 *1 11 1 1   1                                  1*
(   18)  76 *1 11 11 1 1                                     *
(   19) 105 *1111 1 11                                       *
(   20) 106 *1111 111                                        *
(   21) 107 * 111 11 1                                       *
(   22) 108 * 1 1 11 1                                     1*
(   23) 109 *111 1 111                                       *
(   24) 110 *111   1 1                              1       *
(   25) 111 * 11   111                                       *
```

```
(  26)  112   * 1 111   1                                                        *
(  27)  113   *1 1111111                                                         *
(  28)  114   * 1 1 11                                                           *
==========  *================================================================*
(  29)    8   *              11 11   1                                          *
(  30)   11   *              11 11 1 1                                          *
(  31)   14   *              1 11   11                                     1    *
(  32)   19   *               1 11 1 1                                         *
(  33)   53   *              11111 1                                           *
(  34)   55   *               1111111                                         *
(  35)   58   *              111 111 1                                         *
(  36)   59   *               1 111 1                                         *
(  37)   71   *               11111111                                        *
(  38)   73   *              111111                                           *
(  39)   74   *              11   11 1                                         *
(  40)   78   *              11   11 1                                         *
(  41)   79   *              111111 1                                         *
(  42)   81   *               11111111                                        *
(  43)   83   *               1 111 11                      1                 *
(  44)   84   *           1  1 1 1 111                                         *
(  45)   85   *                 1 1  11                                        *
(  46)   86   *   1         1 11111 1                                          *
(  47)   87   *              1 111 11                                          *
(  48)   88   *               111111                         1                *
(  49)   89   *               111 1111                    1                   *
(  50)   93   *              1111111 1                                         *
(  51)   97   *               1       1                                        *
(  52)  141   *               1 11 1 1                                         *
(  53)  142   *               1111 1 1                                         *
(  54)  143   *              1 111 11                                          *
==========  *================================================================*
(  55)   21   *                      111                                       *
(  56)   22   *                      1                                         *
(  57)   34   *                      1111                                      *
(  58)   38   *                      1111                                      *
(  59)   42   *                      1 1         1                             *
(  60)   43   *                      1 11                                      *
(  61)   54   *                       1                                        *
(  62)   56   *                      1  1                                      *
(  63)   57   *                      11                                        *
(  64)   60   *                      1 1                                       *
(  65)   61   *                      111                                       *
(  66)   62   *                      1 1                                       *
(  67)   63   *                      1111                                      *
(  68)   64   *                      1 1  1                                    *
(  69)   65   *              1       111                                       *
(  70)   66   *                       11                                       *
(  71)   80   *                       11                                       *
(  72)   92   *                       11                                       *
(  73)   96   *                     1  1                                       *
(  74)  101   *                       11                                       *
(  75)  102   *                    1   11                                      *
(  76)  103   *                      1                                         *
(  77)  104   *                      1 1                                       *
(  78)  115   *                 1    1 1                                       *
(  79)  116   *                      1 1                                       *
(  80)  117   *                      1 1              1                        *
(  81)  119   *                      1                                         *
(  82)  121   *                       11                                       *
(  83)  123   *          1            11                                       *
(  84)  125   *                      1                                         *
(  85)  127   *                      1 1                                       *
(  86)  129   *                      1 1                                       *
(  87)  131   *                      1 11                                      *
```

```
(  88) 133   *                         1  1                                    *
(  89) 135   *                          1                                       *
(  90) 137   *                         1 1                                      *
(  91) 139   *                         1 1                                      *
(  92) 140   *                         1 1                                      *
==========   *===========================================================*
(  93)   1   *                              1111 1                             *
(  94)   2   *                              11 11 1                            *
(  95)   3   *                              1111                               *
(  96)   4   *                              1111                               *
(  97)   6   *                            1     11                             *
(  98)   9   *                            1     11                             *
(  99)  13   *                            1     11                             *
( 100)  24   *                            1111  1                              *
( 101)  26   *                            1111 1111                            *
( 102)  28   *                             1 111                               *
( 103)  39   *1                           1 11 1     1      1                  *
( 104)  47   *                                11                               *
( 105)  69   *                             1 111                               *
( 106)  90   *                            1     11                             *
( 107)  95   *                             1  11                               *
( 108)  98   *                             1 1   1       1       1             *
( 109)  99   *                             1 1   1                             *
( 110) 100   *                             1  1111                             *
( 111) 126   *                             11111 1                             *
( 112) 128   *                            1 11  1                              *
( 113) 130   * 1                          1111   1     1                       *
==========   *===========================================================*
( 114)  15   *                   1                 1   1111                    *
( 115)  16   *                                      11 111                     *
( 116)  23   *                                    111   11                     *
( 117)  25   *                              1     11   111                     *
( 118)  50   *                               1      111 11                     *
( 119) 144   *                                    1 11 1 1                     *
( 120) 145   *                                     11 1111                     *
( 121) 146   *                                    11111111                     *
( 122) 147   *                                    11111 11     1               *
( 123) 148   *                                    1  11111 1                   *
( 124) 149   *                                    11111111           1         *
( 125) 150   *                                    1   1 11                     *
==========   *===========================================================*
( 126)   5   *                  1                          11 1 1 1            *
( 127)   7   *                              1              11 1 1 1            *
( 128)  12   *             1                                1 111     1*
( 129)  17   *                                              11 111         *
( 130)  20   *                                              1 111          *
( 131)  46   *                                             11 1 1   1      *
( 132)  48   *                                             11   1   1      *
( 133)  49   *                                             11 1     1      *
( 134)  51   *                                             1  1     1 1*
( 135)  52   *                                             1  1 1   1 1*
( 136)  67   *           1                                1 1 11     11*
( 137)  68   *                                             1 11   1 1 *
( 138)  72   *                                             1 11   111 *
( 139)  77   *     1                                       1 11   1 1 *
( 140)  82   *                                         1  1 1     1 11*
( 141)  91   *                                              1 1 1    1*
( 142)  94   *                                             11 1 1   1  *
( 143) 118   *                                             1111111       *
( 144) 120   *                                             111    1       *
( 145) 122   *                                             111    1       *
( 146) 124   *                                             11 1   1      *
( 147) 132   *                                             1 1        11*
( 148) 134   *                                             1  1 1  1111*
```

```
( 149) 136  *                                          1 1 11  1 1 *
( 150) 138  *                     1                     1 1 11  1  1*
==========  *****************************************************
```

< Machine cells and Part families >
```
============================================================
Machine Cell[ 1] = { 3, 7, 12, 26, 32, 38, 40, 46, 49 }
Machine Cell[ 2] = { 4, 5, 8, 9, 20, 22, 37, 39, 50 }
Machine Cell[ 3] = { 6, 23, 34, 48 }
Machine Cell[ 4] = { 1, 2, 11, 13, 16, 30, 35, 42 }
Machine Cell[ 5] = { 14, 15, 17, 18, 33, 36, 45, 47 }
Machine Cell[ 6] = { 10, 19, 21, 24, 25, 27, 28, 29, 31, 41, 43, 44 }
============================================================
Part  Family[ 1] = { 10, 18, 27, 29, 30, 31, 32, 33, 35, 36, 37, 40, 41,
44, 45, 70, 75, 76, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114 }
Part  Family[ 2] = { 8, 11, 14, 19, 53, 55, 58, 59, 71, 73, 74, 78, 79,
81, 83, 84, 85, 86, 87, 88, 89, 93, 97, 141, 142, 143 }
Part  Family[ 3] = { 21, 22, 34, 38, 42, 43, 54, 56, 57, 60, 61, 62, 63,
64, 65, 66, 80, 92, 96, 101, 102, 103, 104, 115, 116, 117, 119, 121, 123,
125, 127, 129, 131, 133, 135, 137, 139, 140 }
Part  Family[ 4] = { 1, 2, 3, 4, 6, 9, 13, 24, 26, 28, 39, 47, 69, 90, 95,
98, 99, 100, 126, 128, 130 }
Part  Family[ 5] = { 15, 16, 23, 25, 50, 144, 145, 146, 147, 148, 149, 150
}
Part  Family[ 6] = { 5, 7, 12, 17, 20, 46, 48, 49, 51, 52, 67, 68, 72, 77,
82, 91, 94, 118, 120, 122, 124, 132, 134, 136, 138 }
============================================================
```

< Summary of the performance measures >
```
============================================================
No. of machines                              = 50
No. of part types                            = 150
No. of cells                                 = 6
Machine cell size                            = 12
Total no. of 1's in the original MPIM : |A| = 726
Matrix density                               = 0.0968
Total no. of within-block 1's                = 681
No. of exceptional elements (EEs)            = 45
No. of voids                                 = 521
Sum of EEs and voids                         = 566
Group Cability Index (GCI)                   = 93.80 %
grouping efficiency (GE)                      = 77.97 %
Grouping efficacy (GF)                        = 54.61 %
Machine utilization (MU)                      = 56.66 %
No. of redundant machines (RMs)              = 0
============================================================
```