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Design of Cellular Layout

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Abstract

Cellular manufacturing is a type of layout where machines are grouped according to the process requirements for a set of similar items (part families) that require similar processing. These groups are called cells. Therefore, a cellular layout is an equipment layout configured to support cellular manufacturing. Processes are grouped into cells using a technique known as group technology (GT). Group technology involves identifying parts with similar design characteristics (size, shape, and function) and similar process characteristics (type of processing required, available machinery that performs this type of process, and processing sequence). Workers in cellular layouts are cross-trained so that they can operate all the equipment within the cell and take responsibility for its output. Sometimes the cells feed into an assembly line that produces the final product. In this paper we are going to design a cellular layout for a simple problem.

Keywords: *Cellular laout, machines, group technology, workers, cell.*

1. Introduction

Cellular manufacturing is a type of layout where machines are grouped according to the process requirements for a set of similar items (part families) that require similar processing. These groups are called cells. Therefore, a cellular layout is an equipment layout configured to support cellular manufacturing. Processes are grouped into cells using a technique known as group technology (GT). Group technology involves identifying parts with similar design characteristics (size, shape, and function) and similar process characteristics (type of processing required, available machinery that performs this type of process, and processing sequence). Workers in cellular layouts are cross-trained so that they can operate all the equipment within the cell and take responsibility for its output. Sometimes the cells feed into an assembly line that produces the final product. In some cases a cell is formed by dedicating certain equipment to the production of a family of parts without actually moving the equipment into a physical cell (these are called virtual or nominal cells). In this way, the firm avoids the burden of rearranging its current layout. However, physical cells are more common. A cell is created by consolidating the processes required to create a specific output, such as a part or a set of instructions. These cells allow for the reduction of extraneous steps in the process of creating the specific output, and facilitate quick identification of problems and encourage communication of employees within the cell in order to resolve issues that arise quickly. Once implemented, cellular manufacturing has been said to reliably create massive gains in productivity and quality while simultaneously reducing the amount of inventory, space and lead time required to create a product. It is for this reason that the one-piece-flow cell has been called "the ultimate in lean production". In this paper we are going to design a cellular layout for a simple problem.

2. Literature Review

Anand Jayakumar A and Krishnaraj C [1] have created a mathematical revenue model for multiple customer segments. Anand Jayakumar A et al [2] have optimized a p median problem using python. Anand Jayakumar A et al [3] have optimized a fixed charge problem using python. Anand Jayakumar A and Krishnaraj C [4] have created a mathematical model for pricing and revenue management of perishable assets. Anand Jayakumar A and Krishnaraj C [5] have suggested on implementation of quality circle. Anand Jayakumar A et al [6] have suggested a mixed strategy for aggreage planning. Anand Jayakumar A et al [7] have created a mathematical model for aggregate planning. Anand Jayakumar A et al [8] have created a mathematical model for supply chain network design. Anand Jayakumar A et al [9] have created a mathematical model for aggregate planning for a pump manufacturing company. Anand Jayakumar A et al [10] have improved productivity in a stitching section. Anand Jayakumar A et al [11] have created another model for aggregate planning. Anand Jayakumar A et al [12] have reviewed on the mathematical models for supply chain network design. Anand Jayakumar A et al [13] have created a chase strategy for aggregate production planning. Anand Jayakumar A and Krishnaraj C [14] have created a mathematical model for supply chain network optimization using gravity location method. Krishnaraj C et al [15] have solved a supply chain network optimization model. Anand Jayakumar A et al [16] have presented a supply chain location allocation problem in multiple stages and dedicated supply. Anand Jayakumar A et al [17] have presented a facility layout problem.

3. The Mathematical Model

Given m machines and n parts, it is required to group them into p machine cells and part families. Several formulations exist and we present one such formulation.

Let Xik = 1 if machine I is in group k
= 0 otherwise
Let Yjk = 1 if part j is in group k
= 0 otherwise
Let aij = 1 if part (or component) visits machine i
= 0 otherwise
(The aij values are available in the machine – component incidence matrix.)

Each machine belongs to only one group and each part belongs to one group. These are modeled as

$\sum_{k=1}^{p} Xik$ = 1 for all i

$\sum_{k=1}^{p} Yik$ = 1 for all j

Xik, Yjk = 0,1

There is an intercell move if part requires a machine and if the part and machine are in two different groups. The objective is to

Minimize $\sum_{k=1}^{p} \sum_{i=1}^{m} \sum_{j=1}^{n} aij \mid Xik - Yjk \mid$

The above problem is a zero-one problem, but is not linear because of the absolute value term in the objective function. There are ways to modify the objective function to a linear objective function by introducing extra variables and constraints.

The above problem is a zero-one problem, but is not linear because of the absolute value term in the objective function. There are ways to modify the objective function to a linear objective function by introducing extra variables and constraints.

4. The Problem

In cellular manufacturing, the machines are divided into cells and parts are divided into families such that the parts within a cell are entirely manufactured within the assigned cell. This manufacturing system provides the advantages of the line layout in the process type batch manufacturing.

We now address the problem of identifying machine cells and part families for cellular layout. We provide several models and algorithms that help us in identifying part families and machine cells.

We represent the processing information between the machines and parts using a zero-one matrix called machine-component incidence matrix. A typical machine-component matrix is shown in Table 1 below.

Table 1: Machine-component incidence matrix

	1	2	3	4	5	6	7	8
1		1		1	1	1	1	
2	1		1		1			1
3		1				1	1	1
4	1	1		1		1	1	
5	1		1					1
6	1				1			1

The rows represent the machines and the columns represent the parts (or components). As mentioned earlier, the ideal situation is to have machine cells and associated part families such that all the parts within a cell are entirely manufactured within the associated assigned cell. In situations where this is not possible, components belonging to a cell require to visit a machine in another cell. This is called an intercell move and we have to minimize the intercell moves. The number of machine cells and part families required can be specified by the user.

5. About LINGO

LINGO is a simple tool for utilizing the power of linear and nonlinear optimization to formulate large problems concisely, solve them, and analyze the solution. Optimization helps you find the answer that yields the best result; attains the highest profit, output, or happiness; or achieves the lowest cost, waste, or discomfort. Often these problems involve making the most efficient use of your resources—including money, time, machinery, staff, inventory, and more. Optimization problems are often classified as linear or nonlinear, depending on whether the relationships in the problem are linear with respect to the variables. LINGO includes a set of built-in solvers to tackle a wide variety of problems. Unlike many modeling packages, all of the LINGO solvers are directly linked to the modeling environment. This seamless integration allows LINGO to pass the problem to the appropriate solver directly in memory rather than through more sluggish intermediate files. This direct link also minimizes compatibility problems between the modeling language component and the solver components. Local search solvers are generally designed to search only until they have identified a local optimum. If the model is non-convex, other local optima may exist that yield significantly better solutions. Rather than stopping after the first local

optimum is found, the Global solver will search until the global optimum is confirmed. The Global solver converts the original non-convex, nonlinear problem into several convex, linear subproblems. Then, it uses the branch-and-bound technique to exhaustively search over these subproblems for the global solution. The Nonlinear and Global license options are required to utilize the global optimization capabilities.

6. LINGO Program

```
Model:
a11 = 0; a12 = 1; a13 = 0; a14 = 1; a15
= 1; a16 = 1; a17 = 1; a18 = 0;
a21 = 1; a22 = 0; a23 = 1; a24 = 0; a25
= 1; a26 = 0; a27 = 0; a28 = 1;
a31 = 0; a32 = 1; a33 = 0; a34 = 0; a35
= 0; a36 = 1; a37 = 1; a38 = 1;
a41 = 1; a42 = 1; a43 = 0; a44 = 1; a45
= 0; a46 = 1; a47 = 1; a48 = 1;
a51 = 1; a52 = 0; a53 = 1; a54 = 0; a55
= 0; a56 = 0; a57 = 0; a58 = 1;
a61 = 1; a62 = 0; a63 = 0; a64 = 0; a65
= 1; a66 = 0; a67 = 0; a68 = 1;

MIN = a11 * @ABS(X11 - Y11) + a12 *
@ABS(X11 - Y21) + a13 * @ABS(X11 - Y31)
+ a14 * @ABS(X11 - Y41) + a15 *
@ABS(X11 - Y51) + a16 * @ABS(X11 - Y61)
+ a17 * @ABS(X11 - Y71) + a18 *
@ABS(X11 - Y81)
    + a21 * @ABS(X21 - Y11) + a22 *
@ABS(X21 - Y21) + a23 * @ABS(X21 - Y31)
+ a24 * @ABS(X21 - Y41) + a25 *
@ABS(X21 - Y51) + a26 * @ABS(X21 - Y61)
+ a27 * @ABS(X21 - Y71) + a28 *
@ABS(X21 - Y81)
    + a31 * @ABS(X31 - Y11) + a32 *
@ABS(X31 - Y21) + a33 * @ABS(X31 - Y31)
+ a34 * @ABS(X31 - Y41) + a35 *
@ABS(X31 - Y51) + a36 * @ABS(X31 - Y61)
+ a37 * @ABS(X31 - Y71) + a38 *
@ABS(X31 - Y81)
    + a41 * @ABS(X41 - Y11) + a42 *
@ABS(X41 - Y21) + a43 * @ABS(X41 - Y31)
+ a44 * @ABS(X41 - Y41) + a45 *
@ABS(X41 - Y51) + a46 * @ABS(X41 - Y61)
+ a47 * @ABS(X41 - Y71) + a48 *
@ABS(X41 - Y81)
    + a51 * @ABS(X51 - Y11) + a52 *
@ABS(X51 - Y21) + a53 * @ABS(X51 - Y31)
+ a54 * @ABS(X51 - Y41) + a55 *
@ABS(X51 - Y51) + a56 * @ABS(X51 - Y61)
+ a57 * @ABS(X51 - Y71) + a58 *
@ABS(X51 - Y81)
    + a61 * @ABS(X61 - Y11) + a62 *
@ABS(X61 - Y21) + a63 * @ABS(X61 - Y31)
+ a64 * @ABS(X61 - Y41) + a65 *
@ABS(X61 - Y51) + a66 * @ABS(X61 - Y61)
+ a67 * @ABS(X61 - Y71) + a68 *
@ABS(X61 - Y81)

    + a11 * @ABS(X12 - Y12) + a12 *
@ABS(X12 - Y22) + a13 * @ABS(X12 - Y32)
+ a14 * @ABS(X12 - Y42) + a15 *
@ABS(X12 - Y52) + a16 * @ABS(X12 - Y62)
+ a17 * @ABS(X12 - Y72) + a18 *
@ABS(X12 - Y82)
    + a21 * @ABS(X22 - Y12) + a22 *
@ABS(X22 - Y22) + a23 * @ABS(X22 - Y32)
+ a24 * @ABS(X22 - Y42) + a25 *
@ABS(X22 - Y52) + a26 * @ABS(X22 - Y62)
+ a27 * @ABS(X22 - Y72) + a28 *
@ABS(X22 - Y82)
    + a31 * @ABS(X32 - Y12) + a32 *
@ABS(X32 - Y22) + a33 * @ABS(X32 - Y32)
+ a34 * @ABS(X32 - Y42) + a35 *
@ABS(X32 - Y52) + a36 * @ABS(X32 - Y62)
+ a37 * @ABS(X32 - Y72) + a38 *
@ABS(X32 - Y82)
    + a41 * @ABS(X42 - Y12) + a42 *
@ABS(X42 - Y22) + a43 * @ABS(X42 - Y32)
+ a44 * @ABS(X42 - Y42) + a45 *
@ABS(X42 - Y52) + a46 * @ABS(X42 - Y62)
+ a47 * @ABS(X42 - Y72) + a48 *
@ABS(X42 - Y82)
    + a51 * @ABS(X52 - Y12) + a52 *
@ABS(X52 - Y22) + a53 * @ABS(X52 - Y32)
+ a54 * @ABS(X52 - Y42) + a55 *
@ABS(X52 - Y52) + a56 * @ABS(X52 - Y62)
+ a57 * @ABS(X52 - Y72) + a58 *
@ABS(X52 - Y82)
    + a61 * @ABS(X62 - Y12) + a62 *
@ABS(X62 - Y22) + a63 * @ABS(X62 - Y32)
+ a64 * @ABS(X62 - Y42) + a65 *
@ABS(X62 - Y52) + a66 * @ABS(X62 - Y62)
+ a67 * @ABS(X62 - Y72) + a68 *
@ABS(X62 - Y82);

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

```
X51 + X52 = 1;
X61 + X62 = 1;

Y11 + Y12 = 1;
Y21 + Y22 = 1;
Y31 + Y32 = 1;
Y41 + Y42 = 1;
Y51 + Y52 = 1;
Y61 + Y62 = 1;
Y71 + Y72 = 1;
Y81 + Y82 = 1;

@BIN(X11); @BIN(X12);
@BIN(X21); @BIN(X22);
@BIN(X31); @BIN(X32);
@BIN(X41); @BIN(X42);
@BIN(X51); @BIN(X52);
@BIN(X61); @BIN(X62);

@BIN(Y11); @BIN(Y12);
@BIN(Y21); @BIN(Y22);
@BIN(Y31); @BIN(Y32);
@BIN(Y41); @BIN(Y42);
@BIN(Y51); @BIN(Y52);
@BIN(Y61); @BIN(Y62);
@BIN(Y71); @BIN(Y72);
@BIN(Y81); @BIN(Y82);

End
```

7. Result and Discussion

- Machines 2, 3, 4, 5, 6 are in group 1
- Machines 1 are in group 2
- Parts 1,2,3,4,5,6,7,8 are in group 1
- No Parts are in group 2

8. Conclusion

Thus we have solved a simple cellular layout problem using linear programming method.

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