

Design of Manufacturing Layout using Craft Algorithm

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ABSTRACT

A typical manufacturing plant has number of diverse activities interacting with each other. Facilities layout consists of the production areas and personnel areas within the building. Plant layout design is one of the strategic fields that determine the long run efficiency of operation. Facility Layout Problem involves the positioning of cells within a given area so as to minimize the material flow costs between cells. The Layout Design Problem is both tactically and strategically important since the layout plays a large role in determining the efficiency and flexibility of the manufacturing plant. Flexible Plant Layout algorithm is used to minimize the material handling cost and deal with the changes in future. In this project CRAFT (Computerized Relative Allocation of Facilities Technique) algorithm is used for designing of plant layout. CRAFT algorithm is one of the most developed and used algorithm for design or optimizing a facility layout which mainly emphasis on the material handling cost and the layout cost.

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Introduction

Any manufacturing plant has more number of diverse activities are inter connected based on the functions. In addition to areas specifically related to production, there must be dressing rooms, lunch room and restrooms for employees; offices for supervision, design and production control; and space for inventory and aisles. Thus, raw materials arrive at a shipping dock, they are unpacked and checked in a quality control area, they may then be processed through several processing areas and finally the finished product again passes through the shipping dock. In fact, a plant may be viewed as a large number of finite geometric areas arranged on the floor space of the building. The problem of arranging these areas in an effective manner is very critical.

Clearly, the layout problem has relevance in many areas of facility and equipment design, from the layout of the rooms in a home to the layout of chips on an electronic circuit board. Although the facility layout problem may arise in many contexts, in this section we assume we are dealing with a plant manufacturing products for sale.

Facilities location is about placement of the facility on a specific plot of land with respect to customers, suppliers and other facilities. Facilities design consists of the facility systems design, the layout design and the handling systems design. The facility systems consist of the structural systems, the environmental systems, the lighting/electrical systems and safety systems. The layout consists of all equipment, machinery and furnishings within the building structure. The handling system consists of the mechanisms needed to satisfy the required facility interactions. For a manufacturing plant, the facilities layout also called plant layout, consists of the production areas, production related or support areas and personnel areas within the building.

II. Objectives of the Plant Layout Strategy

Some typical plant layout objectives are to

- Meet the economic demand: minimize investment in equipment and material handling cost.
- Meet the requirement of product design and volume.

- Meet the requirement of process equipment and capacity: minimize overall Production time; maintain flexibility of arrangement and operation; Minimize variation in types of material handling equipment; facilitate the manufacturing process.

- Meet the requirement of quality of work life: provide for employee convenience, safety and comfort; facilitate the organizational structure.

- Meet the requirement of building and site constraints: utilize existing space most effectively.

2.1 Organization of the work

Step 1: First we gather the required information such as inputs data required for optimization and selecting the Algorithm for optimization.

Step 2: Now with the gathered information we draw a layout diagram which acts as the initial layout for the algorithm in design software like AUTO CAD.

Step 3: Now converting the line diagram from AUTO CAD.

Step 4: Converting the AUTOCAD into a STEP file format.

Step 5: Calculate the relation between machines in layout.

Step 6: From the obtained STEP File we can calculate the distance between the machines in the layout.

Step 7: Now with the collected data we first calculate the part flow matrix which acts as one of the input to the CRAFT Algorithm.

Step 8: With the distance as the other input and cost matrix as another input first we calculate the initial cost of the layout.

Step 9: Now we are using programming software to perform the optimization.

Step 10: Calculating the least of the travelling cost of the layout.

2.2 Summary

A good layout well suited to the manufacturing philosophy is the fundamental starting point for total production system design. Because the volume and the mix of products to be produced is typically not known with certainty nor is it static over time is known.

Despite many existing layout design procedures the designed layouts have sufficient flexibility to meet the actual stochastic production requirements. Flexible layout should give factories many practical advantages to remain competitive and on the first class level.

III. Development of CRAFT Algorithm Using Java Program

3.1 Introduction

CRAFT (Buffa et al., 1964) is a computerized heuristic algorithm that takes in *load matrix* of interdepartmental flow and transaction costs with a representation of a block layout as the inputs. The block layout could either be an existing layout or; for a new facility. Any arbitrary initial layout. The algorithm then computes the department allocations and returns an estimate of the total interaction costs for the initial layout. The governing algorithm is designed to compute the impact on a cost measure for two-way or three-way swapping in the location of the facilities. For each swap, the various interaction costs are computed afresh and the load matrix and the change in cost (increase or decrease) is noted and stored in the RAM. The algorithm proceeds this way through all possible combinations of swaps accommodated by the software.

The basic procedure is repeated a number of times resulting in a more efficient block layout every time till such time when no further cost reduction is possible. The final block layout is then printed out to serve as the basis for a detailed layout template of the facilities at a later stage.

Since its formulation, more powerful versions of CRAFT have been developed but these too follow the same, basic heuristic routine and therefore tend to be highly CPU-intensive. The basic computational disadvantage of a CRAFT-type technique is that one always has got to start with an arbitrary initial solution. This means that there is no mathematical certainty of attaining the desired optimal solution after a given number of iterations. If the starting solution is quite close to the optimal solution by chance, then the final solution is attained only after a few iterations.

However, as there is no guarantee that the starting solution will be close to the global optimum, the expected number of iterations required to arrive at the final solution tend to be quite large thereby straining computing resources. In our present paper we propose and illustrate the Modified Assignment (MASS) algorithm as an extension to the traditional CRAFT to enable faster convergence to the optimal solution. As our proposed algorithm is semi-heuristic, it is likely to be less CPU-intensive than any traditional, purely heuristic CRAFT-type algorithm.

3.2 Mathematical Form:

The craft model is mathematically represented as the following

The main objective of the layout is to minimize total cost (TC) function, and the problem can be specified as:

$$\text{Minimize TC} = \sum_{i=1}^n \sum_{j=1}^n D_{ij} * W_{ij} * C_{ij}$$

More formally,

D_{ij} represent the distance respectively between departments i and j ,

W_{ij} inter-departmental traffic respectively between departments i and j and.

C_{ij} cost respectively between departments i and j .

CRAFT has some assumptions: there are no "negative" relationships; all flows start and stop at department centroids; all movements are rectilinear; move costs are independent of

equipment utilization; and move costs are linear with distance.

CRAFT needs the following input data: initial layout (building dimensions, number of departments, department's areas, Departments position); from-to material-flow matrix; move cost matrix; and number and location of fixed departments. CRAFT has the following parameters to control the algorithm: same area interchange restriction to be relaxed to varying degrees; two or three-way interchanges and significant level to make exchanges.

CRAFT uses dummy departments for the following purposes: fixed to a specific area; make layout rectangular or square; represent fixed facilities such as stairways, elevators, restrooms and docks; represent aisles; and fill building.

3.3 CRAFT procedures:

- Place the layout on a coordinate system.
- Determine the centroids of the departments in initial layout.
- Calculate distance matrix between departments.
- Calculate the transportation cost by multiplying the distance matrix by from-to matrix and by the move cost matrix.
- Make the interchange that offers the greatest estimated reduction in

Transportation costs.

- Check all possible interchanges that have equal areas or common borders.
- Repeat until no improvement is found.

CRAFT can have the following interchanges: pair-wise interchanges; three-way

Interchange; pair-wise followed by three-way interchanges; three-way followed by pair-wise interchanges; the best of pair-wise or three-way interchanges.

CRAFT can do the sensitivity analysis by using various initial layouts or by using various from-to values.

IV. Modeling of Proposed Manufacturing Layout

4.1 Introduction

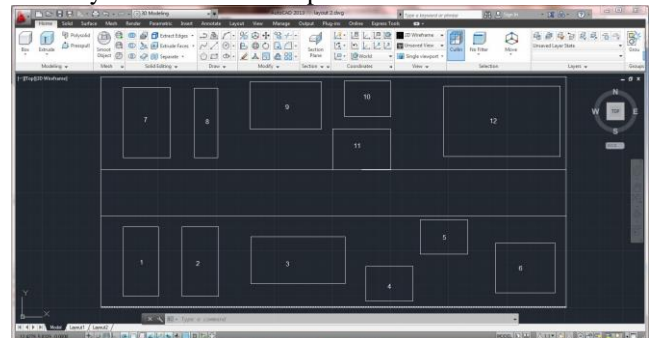
In this chapter we are presenting the data collected and the detail structure of the calculation used in this project and also representing the outputs obtained in the program are also presented below.

➤ Input required to apply craft algorithm

1. Number of departments = 12
2. Initial layout is as shown in file attached.
3. Cost matrix is taken from table 5.2.
4. Flow matrix is as shown below table 5.1.
5. Area of each department is given in the file attached

4.2 Planned view of proposed Layout

Initial layout of the floor shop drawn in AUTOCAD



**Figure 1. layout diagram from AUTOCAD software
Converting the input data into a step file format in order
to calculate the distance from the AUTOCAD software
ISO-10303-21.**

```
/******  
*****  
*   Generated by software with PDElib inside  
*  
*   PDElib Version v51a. created Wed 11/30/2011  
*  
*   ITI Transcendata (http://www.transcendata.com/)  
*  
*****  
*****/  
FILE_DESCRIPTION(("'.2;1');  
FILE_NAME('layout 2.stp'.2014-02-  
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Desktop 2011'.'. ');  
FILE_SCHEMA(('CONFIG_CONTROL_DESIGN'));  
ENDSEC;  
DATA;  
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($..RADIAN.));  
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0.0);  
#12=PLANE_ANGLE_MEASURE_WITH_UNIT(PLANE_  
ANGLE_MEASURE(0.0174532925).#10);  
#16=(CONVERSION_BASED_UNIT('DEGREE'.#12)NAM  
ED_UNIT(#11)PLANE_ANGLE_UNIT());  
#20=(NAMED_UNIT(*)SI_UNIT($..STERADIAN.)SOLID  
_ANGLE_UNIT());  
#24=(LENGTH_UNIT()NAMED_UNIT(*)SI_UNIT(.MILL  
I..METRE.));  
#26=UNCERTAINTY_MEASURE_WITH_UNIT(LENGTH  
_MEASURE(0.000001).#24.'DISTANCE_ACCURACY_  
VALUE'.);  
#28=(GEOMETRIC_REPRESENTATION_CONTEXT(3)G  
LOBAL_UNCERTAINTY_ASSIGNED_CONTEXT((#26))  
GLOBAL_UNIT_ASSIGNED_CONTEXT((#16.#20.#24))R  
EPRESENTATION_CONTEXT('3D');  
#29=APPLICATION_CONTEXT('CONFIGURATION  
CONTROLLED 3D DESIGNS OF MECHANICAL PARTS  
AND ASSEMBLIES');  
#30=APPLICATION_PROTOCOL_DEFINITION('INTERN  
ATIONAL STANDARD'.config_control_design'.1995.#29);  
#31=MECHANICAL_CONTEXT('3D Mechanical  
Parts'.#29.'mechanical');  
#32=PRODUCT('Product'.Product'.'.(#31));  
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ail'.$.(#32));  
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one'.#34.#33);  
#36=PERSON('1'.Design'.Joe'.$.$.);  
#37=ORGANIZATION($.'None'.None);  
#38=PERSON_AND_ORGANIZATION(#36.#37);  
#39=PERSON_AND_ORGANIZATION_ROLE('design_ow  
ner');  
#40=CC_DESIGN_PERSON_AND_ORGANIZATION_AS  
SIGNMENT(#38.#39.(#32));  
#41=PRODUCT_DEFINITION_FORMATION_WITH_SPE  
CIFIED_SOURCE('None'.None'.#32..BOUGHT.);  
#42=PERSON('2'.Creator'.Joe'.$.$.);  
#43=ORGANIZATION($.'None'.None);  
#44=PERSON_AND_ORGANIZATION(#42.#43);  
#45=PERSON_AND_ORGANIZATION_ROLE('creator');  
#46=CC_DESIGN_PERSON_AND_ORGANIZATION_AS  
SIGNMENT(#44.#45.(#41));
```

```
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pplier');  
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#53=APPROVAL(#52.'None');  
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#55=ORGANIZATION($.'None'.None);  
#56=PERSON_AND_ORGANIZATION(#54.#55);  
#57=APPROVAL_ROLE('approver');  
#58=APPROVAL_PERSON_ORGANIZATION(#56.#53.#5  
7);  
#59=COORDINATED_UNIVERSAL_TIME_OFFSET(8.$..  
EXACT.);  
#60=CALENDAR_DATE(1996.29.5);  
#61=LOCAL_TIME(12.0.0.0.#59);  
#62=DATE_AND_TIME(#60.#61);  
#63=APPROVAL_DATE_TIME(#62.#53);  
#64=CC_DESIGN_APPROVAL(#53.(#41));  
#65=SECURITY_CLASSIFICATION_LEVEL('unclassified'  
);  
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#95=ORGANIZATION($.'None'.None);  
#96=PERSON_AND_ORGANIZATION(#94.#95);  
#97=PERSON_AND_ORGANIZATION_ROLE('creator');
```

```

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#174=CARTESIAN_POINT("(18.770238936687477.8.8329
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#175=POLYLINE('254'.(#171.#172.#173.#174.#171));
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RAMETER.);
#215=CARTESIAN_POINT("(5.052034809571808.5.04234
0227571557.0.0));
#216=DIRECTION("(1.0.0.0.0.0));
#217=VECTOR("#216.20.0);
#218=LINE("#215.#217);
#219=CARTESIAN_POINT("(25.052034809571808.5.0423
40227571557.0.0));
#220=TRIMMED_CURVE('243'.#218.(PARAMETER_VA
LUE(0.0).#215).(PARAMETER_VALUE(1.0).#219)..T...PA
RAMER.);
#221=GEOMETRIC_CURVE_
SET('GCS1'.(#129.#135.#140.#145.#150.#155.#160.#165.#1
70.#175.#180.#185.#190.#196.#202.#208.#214.#220));
#222=GEOMETRICALLY_BOUNDED_WIREFRAME_SH
APE_REPRESENTATION('GBWSR1'.(#221).#28);
#223=SHAPE_REPRESENTATION_RELATIONSHIP('SR
RPL1'.#222.#122);
ENDSEC; END-ISO-10303-21;
```

The distances are calculated by using the java program which takes the STEP file of the AutoCAD software as the input to the program and the output is shown in the table below.

Entering text

Figure 2. Output Distance Matrix from Java Program.

Now the part handling matrix is derived as the combination of the part flow matrix and Handling cost.

4.3 Part Flow Matrix

The part flow matrix is the density of parts flowing from one machine to another as per the flow in the machine shop it help to understand how one machine is related to another in a machine shop.

The part flow matrix is obtained is shown below table.

Table 1. part flow matrix.

From /To	1	2	3	4	5	6	7	8	9	10	11	12
1	0	3	2	2	1	3	0	2	1	4	2	1
2	3	0	2	3	2	4	1	0	0	3	1	2
3	2	2	0	1	0	2	2	3	2	0	3	2
4	2	3	1	0	2	3	3	2	1	0	2	1
5	1	2	0	2	0	1	3	0	1	2	2	1
6	3	4	2	3	1	0	2	1	0	3	1	1
7	0	1	2	3	3	2	0	2	3	0	1	3
8	2	0	3	2	0	1	2	0	3	2	2	0
9	1	0	2	1	1	0	3	3	0	2	2	3
10	4	3	0	0	2	3	0	2	2	0	2	1
11	2	1	3	2	2	1	1	2	2	2	0	2
12	1	2	2	1	1	1	3	0	3	1	2	0

4.4 Unit Part Handling Matrix:

The part handling cost for each machine is given below

Table 2. Unit Handling Cost.

From /To	1	2	3	4	5	6	7	8	9	10	11	12
1	0	6	8	4	7	3	4	11	9	4	7	5
2	6	0	5	7	9	4	6	6	3	5	11	8
3	8	5	0	6	9	8	12	4	6	8	10	6
4	4	7	6	0	4	3	8	6	12	9	7	8
5	7	9	9	4	0	6	8	5	10	9	6	8
6	3	4	8	3	6	0	5	7	4	8	9	6
7	4	6	12	8	8	5	0	7	3	5	10	8
8	11	6	4	6	5	7	7	0	4	9	7	5
9	9	3	6	12	10	4	3	4	0	6	9	7
10	4	5	8	9	9	8	5	9	6	0	10	6
11	7	11	10	7	6	9	10	7	9	10	0	8
12	5	8	6	8	8	6	8	5	7	6	8	0

Now by multiplying the part flow matrix with the unit handling matrix we get the handling cost matrix with the part flow

where it is taken as the as the input for the CRAFT Algorithm and it taken as diagonal matrix because the values in the part flow matrix for machine X to machine Y is same as the part flow from Machine Y to machine X. so, here we are considering single value.

By considering the diagonal matrix we also reduce the repeated values and the calculation is also made simpler without any errors.

4.5 Part Handling Cost Matrix:

Figure 3. Product of Part Flow and Unit Handling Matrix.

Now travelling cost is calculated from product of the above part handling matrix and the distance obtained from the step file program we calculate the distance matrix between the machines in the layout.

4.6 Manual Calculations

Here, we are showing the manual calculation for the craft algorithm using the tabulated values obtained from the above tables 5.3 and fig 5.2.

$$\begin{aligned}
 \text{Total travelling cost (TC)} &= \sum_{i=1}^n \sum_{j=1}^n D_{ij} * W_{ij} * C_{ij} \\
 &= (18*9.15)+(16*10.09)+(8*15.28)+(7*22.72)+(9*16.79)+(2 \\
 &2*9.97)+(9*13.78)+(16*19.78)+(14*21.64)+(5*17.72)+(21* \\
 &15.28)+(18*22.77)+(16*16.79)+(6*9.15)+(15*19.78)+(16*2 \\
 &1.64)+(16*21.6)+(6*17.995)+(16*19.503)+(2411.86)+(12*1 \\
 &2.68)+(12*16.49)+(15*24.35)+(12*20.43) =14.158.72
 \end{aligned}$$

4.7 Travelling Cost Calculations

The travelling cost on individual group machines are shown above with their distance obtained from the java program and the flow is taken from the table5.3 the above table shows the travelling cost for initial layout and the optimization is done by re-arranging the machines and calculating the distance from the java program.

Figure 4.Traveling Cost Obtained From the Java Program.

The optimization of the travelling cost is calculated using java program where the best layout with optimal cost for this problem is given in the below table.

Figure 5.Optimal Cost of the Layout.

V. Results and Discussion

The project is mainly emphasized on how to reduce the traveling cost of the machine shop layout which is the main criteria for many industries trying many techniques to optimization of layout. In this project one of the oldest but efficient algorithm with combination of the JAVA program is applied which made the work of optimization a bit easy and with the help of the program we can optimize the result without any error of calculation.

The table below shows the results of the travelling cost of the initial layout and the optimal layout.

Initial Sequence of Machines	Travelling Cost
1→2→3→4→5→6 7→8→9→10→11→12	14158.72
1→2→3→4→5→8 12→11→10→6→7→9	2311.68

From the above result it is observed that the initial layout is very high but by application of the craft algorithm it has been reduced to a greater extent by finding the optimal sequence of the machines arrangement in a shop floor such that the material handling cost of the part if minimized as per the considerations of the described algorithm.

VI. Conclusions

The main objective of the thesis is to construct a plant layout where by considering all the factors affecting the layout of the machine shop such as size, space, width and many aspects of the shop floor.

In this project the distance matrix is derived by using the latest drawing software called AUTOCAD 2013 in which a special feature called generating of STEP file which is taken

as input to the java program to calculate the distance between each machines in the layout.

In this work we are using java program to optimize the initial layout using CRAFT algorithm for more machines in short span of time and without any errors in calculation.

Scope of future work:

- In this project the plant layout is designed in AUTOCAD 2013 which is taken as input. But it can be extended to deriving the output to any image format.
- The machine shop can be increased in terms of number of machine for effective calculation of the travelling cost.
- The step file format can be useful for many type of works such as process planning and feature recognition software analysis.
- Java is one of the best programming language to build a software interface between the machine shop and very easy to design a application for mechanical work such as time calculation, cost calculation etc.

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