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Blocplan For Windows: Computer Aided Facility Layout Methodology And Enhancements

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Abstract

Facility layout involves the arrangement of departments in a facility to optimize the performance of the entire system that is contained in the layout. The layout system described in this paper is called BLOCPLAN for Windows which is an evolutionary development of the DOS version of BLOCPLAN. In addition to taking advantage of the graphical Windows interface, this system includes other enhancements over the DOS version. BLOCPLAN for Windows uses rectangular departments and a "banding" procedure to place them in the layout. For a nine department problem the number of possible layouts is close to 20 million. For a 15 department layout there more than 2.6 E 13 possibilities. There are several scoring procedures that are used to evaluate a layout. A Muther Relationship Chart is entered, and this chart may be used for some of the scoring options.

Keywords

Facility, Layout, Computer, Aided, Layout

1. Introduction

Facility layout involves the arrangement of departments in a facility. The objective of facility layout analysis is to develop layouts which maximize the advantageous placement while minimizing the disadvantageous placement of departments. Computers have been utilized since the 1960's and 1970's to assist with the high computational demands required for the calculations necessary for producing these types of facility layouts. Examples include CRAFT and ALDEP [1] [2]. However, it has only been with the advent of the personal computer has Computer Aided Facility Layout software started to reach its full potential with programs such as BLOCPLAN, LOGIC, and MCRAFT, and SPIRAL [3-7]. Most recently, the inherently graphical process of laying out floor plans can now be easily supported with graphically oriented Computer Aided Facility Layout software applications.

The Microsoft Windows environment in particular allows Computer Aided Facility Layout programs to be more user friendly and intuitive. The ability to easily view and output the results of different type of facility layout configurations greatly increases the ability of the analyst to generate, evaluate, and select the most effective alternatives.

This paper describes a new Microsoft Windows based Computer Aided Facility Layout software application, BLOCPLAN for Windows. BLOCPLAN for Windows is an evolutionary development of the DOS version of BLOCPLAN which is currently in use in both academia and industry throughout the world.

2. Background

BLOCPLAN-WIN is a facility layout system that has been developed at the Industrial Engineering Department of the University of Houston. It is intended for use on PC personal computers. There have been earlier versions of BLOCPLAN-WIN that have been developed. These earlier versions were used with a DOS operating system. The current version of the program is BLOCPLAN-WIN. Many of the limitations of the earlier DOS versions have been overcome. In addition, there have been a number of new options that have been included in the new version. The program generates and evaluates block type layouts in response to user supplied data. It is used for single story (site) layouts. BLOCPLAN uses a "banding" procedure to develop single story (site) layouts. This permits a large variety of possible layouts for a problem. For a nine department problem, the number of possible layouts is close to 20 million, and for a 15 department layout there are more than 2.6×10^{13} possibilities. Each department will also be rectangular in shape. The structure that holds the departments will also be rectangular in shape, and the user may

select the length/width ratio of the structure. There are several scoring procedures that may be used to evaluate a layout. The user first inputs the names and the areas of the departments to be included in the layout. He/she then inputs the Muther Relationship Chart values that pertain to the problem. Most facility layout programs seek the layout that will attempt to minimize the material handling activity for the problem. This objective approach to the problem is not the only solution technique that may apply in many situations. There may be other factors that have to be considered. There could be vibration problems that occur in some department that make it impractical for it to be near another department. Similarly, it would be undesirable to locate a painting department near a grinding or machining department. These factors can very often enter into the layout design. There are other scoring procedures that BLOCPLAN-WIN uses to evaluate a layout and the results obtained from these procedures can be calculated and displayed for each layout that is created.

3. Methodology

Tier / Zone Arrangement

The first concept that will be examined is the tier/zone arrangement used in BLOCPLAN. The user provides the required area for the layout that is to be created. He/she does this by specifying the number of "departments" that are to be included in the layout, and then gives the names and required areas for each of these departments. The system will find the total area for all of these departments, and this will be the required area for the layout. In some situations the site exists where some departments are to be placed. This site may have more area than the total required for all the departments. In this case one, or more, of the "departments" to be entered at the site may be labeled Empty 1 or Empty 2, or some other name. The sum of all the assigned areas and the actual department areas will bring the total sum to the area of the facility where the departments are to be placed.

The user also gives the desired length to width ratio (L/W) for the layout. This is the L/W ratio for the entire facility that will contain the departments. This allows for efficient aisle placement and materials handling. The length and the width of the facility can be calculated using the L/W ratio and the total area. BLOCPLAN uses tiers and zones to develop a layout. The facility is divided into three tiers (bands) containing three zones each. The top tier has zones A, B, and C. The middle tier has zones D, E, and F. The third or bottom tier has zones G, H, and I.

Each zone is also sub-divided into two sub-zones, L and R. AL refers to the area in the left portion of zone A, and AR refers to the right side of zone A. Using this notation there are 6 positions that departments can use in Tier 1, 6 positions for Tier 2, and 6 positions for Tier 3. This means that BLOCPLAN can develop layouts for a maximum of 18 departments. Some feel that a limitation of 18 departments is too strict a constraint, and may limit the practical use of BLOCPLAN. However, in most layout problems there are some natural collections of departments, and each of these collections can be treated as one unit. For example, shipping, receiving, and packaging are usually located together, and these can be considered as one unit in a BLOCPLAN analysis. Once the layout has been developed, the positioning of the departments within the collection unit can be done.

Another reason for constraining the number of departments or units in a layout is the evaluation, or scoring procedure. The solution of facility layout problems involves some subjective analysis. Many people, and systems, try to minimize material handling between departments, and use this as the only criteria of the worth of a layout. BLOCPLAN for Windows utilizes the Relationship chart method specified by Muther [8]. With this relationship chart method, a user examines each pair of departments and makes a judgment of how important it is that the pair of departments be close together. Certainly, the amount of material handling between the departments is a factor in this judgment. Muther used the A, E, I, O, U, and X codes. An A relationship indicated that it was "Absolutely Essential" that the departments be close, an E relationship meant that it was "Essential", an I meant that it was "Important", an O means "Ordinary Closeness OK", a U indicated that closeness is "Unimportant", and an X meant that it was "Undesirable" to have them close. The use of relationship charts has proven to play an important role in evaluating and discussing layouts. A relationship chart for 18 "departments" would require 153 entries on the chart (Combinations of 18 things taken 2 at a time). BLOCPLAN allows a user to enter the user code for each pair of departments, in a convenient and user friendly manner. If a layout problem has 50 departments, this would require 1225 entries, (Combination of 50 things taken 2 at a time). If a layout has 100 departments, it would require 4950 entries. ($_{100}C_2$). It can be questioned if accurate relationship charts can be developed for that many entries.

If a user has material handling information concerning a layout, this information can be converted to a relationship chart by BLOCPLAN for Windows. It shows material handling activity, in Moves/Time Period, between each pair of departments.

BLOCPLAN for Windows can develop a Muther type relationship chart from this data. It takes the maximum number of loads between departments in the chart and divides this value by 5. For the nine department layout of Figure 1, suppose the maximum number of loads is 300. Depts 3 and 6 and Depts 6 and 8 each have 300 loads per time period between them. Thus, 300/5 = 60. A relationship code of "A" would be assigned to pairs of departments that have a From/To value in the inclusive interval [241, 300]. An "E" would be assigned for values in the inclusive interval [181, 240], an "I" for values within the interval [121, 180], an "O" for the interval [61, 120], and a "U" for values that are equal to or less than 60. There would be no "X" values (Undesirable) assigned for the chart.

It is interesting to compare Relationship charts for a problem when one is based on subjective judgment, and another based just on material handling. There is usually substantial agreement on many of the codes, but there will be some differences. At one time we considered putting a combination option in BLOCPLAN for Windows, that would automatically combine the two charts into one. However, an algorithm for accomplishing this presented problems.

The number of possible layouts that can be created by BLOCPLAN for Windows for a given problem has been a subject of discussion. Some people feel that the Tier/Zone or "banding" procedure puts a severe restriction on the number of possible layouts. We will demonstrate how this is not the case. Consider a layout that is to contain nine departments. The user has named the departments, and provided the area required for each department. Suppose the total required area is 66,000 square feet. The length to width ratio has been specified by the user as 3/2, or 1.5. Remember that each tier can contain a maximum of six departments. One possible way the departments can be placed is to have six departments on the top tier and three departments on the second. We will use the notation [6, 3] to represent this arrangement. The six departments on the top tier can all be in the A,B,C zones, or they all can be in D,E, and F zones, if the top tier is empty. The three departments in the second tier can be in the D,E, and F zones if the six departments above them are in zones A, B, and C , or they must be in zones G,H, and I if the departments above them are in the second tier. Each arrangement will give the same [6, 3] result. There are 29 possible arrangements for a nine department layout. Each of these arrangements has 362,880, (9 factorial), possible layouts. As an example, suppose the nine departments for our example have the areas shown in the Area Column shown in Figure 2. BLOCPLAN for Windows produced a [2,4,3] layout that is shown in Figure 1. D3 and D6 are the two departments that are placed at the top of the layout. The total area for these two departments is 17,000 square feet. The specified L/W ratio of the layout is 3/2. This gives 29 X 362,880 or 10,523,520 layouts. These layouts would all have the 3/2 length/width ratio. Note that the length to width ratio only applies to the overall layout. The algorithm adjusts the length/width ratios of each individual department to meet the overall layout length/width ratio. It is possible that this may result in the particular layout of a department not being suitable. However, since a number of layouts with similar scores can be generated, it is likely that one or more will be acceptable. Note also, that the specific height of each of the tiers are also determined by the algorithm and is outside of the control of the user.

Figure 1: Layout produced by BLOCPLAN

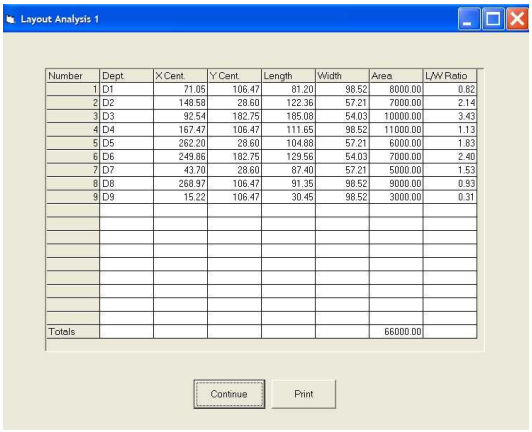

Figure 2: Analysis For Layout in Figure1

It should be emphasized that position in a tier is the important factor. The zone the department is in doesn't matter. The use of the zones is used to fix a department in a location. For example, suppose a user wants a department to be in the upper right hand corner of a facility. He/she would indicate that the department is to be placed in Zone C on the right side (C_R), and the department would be fixed at that point. No department could be to the right of it, and no department could be above it. BLOCPLAN for Windows will also show information concerning the dimensions of the layout. This is obtained by pressing the analysis button in the lower left corner of the layout screen illustrated in Figure 1.

It shows that Department D1 has a length of 81.2 feet and a width of 98.52 feet, so the area of D1 is 81.2 X 98.52 = 7999.8sq. ft.. The specified area of D1 from Figure 2 is 8000 sq. ft, the difference is due to rounding error. The length of the layout in Figure 1 would be equivalent to the sum of the lengths of D3+D6 which is 185.08 + 129.56 which is 314.64. The width would be the sum of the widths of D6 + D8 + D5 which is = 209.68. This gives a L/W ratio of 1.50 which is the specified L/W ratio.

Table 1: Given Relationship Chart for Problem

	D2	D3	D4	D5	D6	D7	D8	D9
D1	A	U	O	U	U	A	O	O
D2		U	E	O	U	I	U	U
D3			U	U	A	U	U	O
D4				O	U	U	O	U
D5					U	O	U	U
D6						U	A	U
D7							U	I
D8								U

The desired relationship chart shown in Table 1 has four 4 A's, 1 E, 2 I's, 1 E, 8 O's, and 21 U's. Suppose the worth vector of the codes are A: 10, E: 5, I: 2, O: 1, U: 1, X: -10. Therefore the total worth of all the positive relationship codes for the problem is 57.

There are several evaluation procedures that are used to score a BLOCPLAN for Windows layout. The first one that will be discussed is the "Adjacency" method. This one uses a relationship chart. The relationship chart can be one that the user furnished, or it can be one that was developed from a From/To chart of material movement. The user is asked to give a vector of the worth of each of the relationship codes. The system has a default vector of values, but the user may change it to any set of values that he/she desires. The default vector has an A=10, E=5, I=2, O=1, U=0, and X=-10. From the relationship chart, the system will count the number of A's in the chart, the number of B's, etc.. Using the chart in Figure 1, it can be seen that there are 4 A's, 1 E, 2 I's, 8 O's, and 21 U's. There were no X codes in this chart. We will use the default vector of the worth of each of the codes. The total worth of all of the codes in this problem would be 57. (4 X 10 + 1 X 5 + 2 X 2 + 8 X 1). Only positive values would be used in getting this sum. A layout that has been created would be examined. For each pair of departments that share a boundary in the layout they would be specified as adjacent. The value of the relationship codes for those pairs of departments would be added. When all values have been added, the sum is divided by the total worth of the relationship chart. Some of these adjacencies could not be satisfied in the layout in Figure 1. The total number of adjacencies satisfied totals 55. The "normalized adjacency score for this layout would be 55/57 or .97 when rounded up. This score is shown on the left hand side of the print out of the layout shown in Figure 1. Note that there were no "X " codes used in this problem.

Another method of scoring a layout is the "Relationship-Distance" procedure. With this procedure the distance (Rectilinear) between the centroids of each pair of departments is multiplied by the numeric worth of the relationship code for the departments. The sum of all of these values is the "Unnormalized Relationship Distance Score" (URDS) for the layout, where the lower the value the better the layout. With this philosophy, departments that have an "A" relationship will be as close together as possible. Departments with an "X" relationship will be as far apart as

possible. BLOCPLAN for Windows attempts to normalize this score. For a given layout a vector of all the distances between departments is created. All of the values in this vector are put in ascending order. A vector of the numeric relationship chart values is also created. These are also put into ascending order from the lowest to the highest. A minimum, or lower bound (LB), for the Relationship Distance Score would be the sum of the products with the highest values in the relationship vector multiplied by the lowest values in the distance vector. BLOCPLAN for Windows also creates an upper bound (UB) for the layout. This value is found by multiplying the largest code values in the numeric relationship vector by the largest values in the distance vector, and summing the results. This value is called the upper bound (UB) for the layout. The normalized relationship distance score would be:

$$(UB - URDS)/(UB - LB) \quad (1)$$

It can be seen from the equation, that when URDS is equal to LB the score would be 1.0, and when URDS is equal to the UB the score would be zero.

Another scoring procedure that BLOCPLAN for Windows presents is simply the total of the material handling activity for the layout. This value is given in Load-Feet, and assumes that the user has given a From/To chart that shows the material handling activity between departments. Again the distance between departments for a layout uses rectilinear distance between department centroids. For any layout that is created by BLOCPLAN Windows, the scores from each of the scoring procedures are reported.

There was a great deal of time spent trying to develop a procedure that would allow BLOCPLAN for Windows to create a near optimal layout from just the information provided by the user. It seemed logical to have departments with a large number of positive relationship code values put in the center of the layout, and pairs of departments that have an "X" relationship code placed on opposite corners of the layout. In early versions of BLOCPLAN for Windows, we had an option called "Layout Algorithm" which attempted to do this. There was still some random placement of departments with the algorithm, so there was some difference in the layouts each time the option was called. However, the option did just not obtain consistently "good" layouts. The procedure that was put in to replace it was the "Automatic Search" algorithm. When this option is selected, BLOCPLAN for Windows will place all of the departments into the layout randomly. There are 18 sites where a department can be placed. (A_L, A_R, B_L,...F_L). For a ten department layout, there would be 43,758 possible site selections (Combinations of 18 things taken 10 at a time ${}_{18}C_{10}$). BLOCPLAN for Windows will find the adjacency score for the random layout. It will then switch the locations of each pair of departments. For example, suppose Dept 1 is in D_R and Dept 2 is in C_L. It will place Dept 1 in C_L and Dept 2 in D_R. It will calculate the adjacency score of this revised layout. If the score is better than the original layout, it will use the revised layout as the starting point and again begin to switch each pair of departments. If there is no improvement for the layout after the switch for departments 1 and 2, it will continue and switch 1 and 3 to see if an improvement can be made. For a 10 department layout, the number of switches that can be made would be 45 [${}_{10}C_2$]. Any time an improvement in the score is made, the revised layout will be the used, and the switching process will begin again with the revised layout. The final layout that will be presented will be the one where all 45 switches have been made with no improvement in the score. The centroids and the dimensions for every department in each layout will be presented when it is created.

Each time the "Automatic Search" algorithm is used, the user must specify the number of layouts that are desired. The maximum number is 20. If 20 layouts are specified, the system will start with a random layout for the first one and keep switching department locations until no further improvements can be made. It will then start with a random layout for the second one and repeat the process. After 20 layouts have been created, they will be presented to the user. The adjacency score, the relationship distance score, and the material handling required for each layout is shown. The user can then ask for 20 more layouts to be created. In a short amount of time the user may review several hundred good layouts. We have found it a good idea to keep a record of the "extra good" layouts that are presented. This scorecard record shows the data of layouts that were created and saved by the user. The adjacency, the relationship distance, and the product movement criteria were used for all the layouts that were created.

4. Summary

The layout of different departments in a facility can have a significant impact on the facilities productivity. Well developed layouts will help reduce non-productive material handling time and costs. BLOCPLAN for Windows offers engineers a user friendly graphical means of analyzing various facility layouts. By using either the Muther

relationship chart or relationship-distance procedure, users can conduct meaningful analysis between different possible layouts.

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