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ASSEMBLY SYSTEM SELECTION CASE STUDY

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ABSTRACT
Recently, more and more often core business of modern enterprises is production including different kinds of assembly processes. The enterprises mainly dealing with assembly are called assembly systems. However, selecting the right system for a product depends on a large number of factors and is not a simple problem. Its solution requires considerable expertise and there is a lack of systematic approaches to support decision making in this area. This paper presents one of the most popular Multi-attribute Utility (MAUT) method for selecting assembly system.
Keywords: Assembly, Selection method, MAUT, Electre.

1. INTRODUCTION

Assembly is required when two or more components need to be brought together in order to produce a product. The assembly phase can also represent a significant proportion of the total production cost of a product and may outweigh the cost of component manufacturing in some industries, ranging from 10 to 50 per cent or more[1].

The design of an assembly system for a particular product is a complex engineering effort involving many interrelated decisions. The wide range of alternative system configurations makes a detailed design of each alternative too expensive and time-consuming[2].

Selecting the most appropriate assembly system can offer enormous benefits in terms of product quality, cost reduction and manufacturing productivity. However, selecting the right system for a product depends on a large number of factors and is not a simple problem. Its solution requires considerable expertise and there is a lack of systematic approaches to support decision making in this area[1].

Decision making based on scientific methodologies is the main goal of organizational managers and system experts. In a traditional Multi Criteria Decision Making (MCDM), each criterion is weighted by a fixed value and the decision maker uses these values to calculate a decision value for each alternative and prioritizes the alternatives based on the calculated decision values, normally in descending order[3]. Making a decision implies that there are alternative choices to be considered, and in such a case we want not only to identify as many of these alternatives as possible but to choose the one that best fits with our goals, objectives, desires, values, and so on[4].

Generally, Multi-Criteria Decision making (MCDM) models have been proposed for complicated decision having multiple optimization assessment criteria. Some uses of MCDM in engineering include flexible manufacturing systems, layout design, integrated manufacturing systems and the evaluation of technology investment decisions[5]

ELECTRE is used to evaluate assembly line alternatives The ELECTRE (for Elimination and Choice Translating Reality.The basic concept of the ELECTRE method is to deal with "outranking relations" by using pairwise comparisons among alternatives under each one of the criteria separately. The outranking relationship of *Ai* v *Aj* describes that even when the *i*-th alternative does not dominate the *j*-th alternative quantitatively, then the decision maker may still take the risk of regarding *Ai* as almost surely beter than *Aj* . In this method following steps are applied.

Step 1. Normalizing the Decision Matrix

This procedure transforms various units in the decision matrix into dimensionless comparable units by using the following equation and Therefore, the normalized matrix **X** is defined as follows

$$x_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{M} a_{ij}^2}}. \qquad X = \begin{bmatrix} x_{11} & x_{12} & x_{13} & \cdots & x_{1N} \\ x_{21} & x_{22} & x_{23} & \cdots & x_{2N} \\ . & & & & . \\ . & & & & . \\ . & & & & . \\ x_{M1} & x_{M2} & x_{M3} & \cdots & x_{MN} \end{bmatrix},$$

Where M is the number of alternatives and N is the number of criteria, and x_{ij} is the new and dimensionless preference measure of the *i*-th alternative in terms of the *j*-th criterion.

Step 2. Weighting the Normalized Decision Matrix

The column of the **X** matrix is then multiplied by its associated weights which were assigned to the criteria by the decision maker. Therefore, the weighted matrix, denoted as **Y**, is:

$$\mathbf{Y} = \begin{bmatrix} y_{11} & y_{12} & y_{13} & \cdots & y_{1N} \\ y_{21} & y_{22} & y_{23} & \cdots & y_{2N} \\ . & & & & . \\ . & & & & . \\ . & & & & . \\ y_{M1} & y_{M2} & y_{M3} & \cdots & y_{MN} \end{bmatrix} = \begin{bmatrix} w_1x_{11} & w_2x_{12} & w_3x_{13} & \cdots & w_Nx_{1N} \\ w_1x_{21} & w_2x_{22} & w_3x_{23} & \cdots & w_Nx_{2N} \\ . & & & & . \\ . & & & & . \\ . & & & & . \\ w_1x_{M1} & w_2x_{M2} & w_3x_{M3} & \cdots & w_Nx_{MN} \end{bmatrix}, \qquad W = \begin{bmatrix} w_1 & 0 & 0 & \ldots & 0 \\ 0 & w_2 & 0 & \ldots & 0 \\ . & & & & . \\ . & & & & . \\ . & & & & . \\ 0 & 0 & 0 & \ldots & w_M \end{bmatrix},$$

$\mathbf{Y} = \mathbf{X}W,$ And $\sum_{i=1}^{N} w_i = 1.$

and also

Step 3. Determine the Concordance and Discordance Sets

The concordance set C_{kl} of two alternatives A_k and A, where $M{\star}k$, $l \geq 1$, is defined as the set of all criteria for which A_k is preferred to A_l. That is, the following is true: $C_{kl} = \{j, \text{ such that: } y_{kj} \geq y_{lj}\}$, for j = 1, 2, 3, ..., N.

The complementary subset is called the discordance set and it is described as follows: $D_{kl} = \{j, \text{ such that: } y_{kj} < y_{lj}\}$, for j = 1, 2, 3, ..., N.

Step 4. Construct the Concordance and Discordance Matrices

The relative value of the elements in the concordance matrix **C** is calculated by means of the concordance index. The concordance index c_{kl} is the sum of the weights associated with the criteria contained in the concordance set. That is, the following is true:

$$C_{kl} = \sum_{j \in C_{kl}} w_j, \quad for \quad j = 1, 2, 3, \ldots, N.$$

The concordance index indicates the relative importance of alternative A_k with respect to alternative A_l. Apparently $0 \leq c_{kl} \leq 1.$ Therefore, the concordance matrix **C** is defined as follows:

$$C = \begin{bmatrix} - & c_{12} & c_{13} & \cdots & c_{1M} \\ c_{21} & - & c_{23} & \cdots & c_{2M} \\ \cdot & & & & \cdot \\ \cdot & & & & \cdot \\ \cdot & & & & \cdot \\ c_{M1} & c_{M2} & c_{M3} & \cdots & - \end{bmatrix}.$$

It should be noted here that the entries of matrix **C** are not defined when $k = l$.
The discordance matrix **D** expresses the degree that a certain alternative A_k is worse than a competing alternative A_l. The elements d_{kl} of the discordance matrix are defined as follows:

$$d_{kl} = \frac{\max_{j \in D_{kl}} |y_{kj} - y_{lj}|}{\max_{j} |y_{kj} - y_{lj}|}. \qquad D = \begin{bmatrix} - & d_{12} & d_{13} & \cdots & d_{1M} \\ d_{21} & - & d_{23} & \cdots & d_{2M} \\ \cdot & & & & \cdot \\ \cdot & & & & \cdot \\ \cdot & & & & \cdot \\ d_{M1} & d_{M2} & d_{M3} & \cdots & - \end{bmatrix}.$$

Step 5. Determine the Concordance and Discordance Dominance Matrices
The concordance dominance matrix is constructed by means of a threshold value for the concordance index. For example, A_k will only have a chance to dominate A_l if its corresponding concordance index c_{kl} exceeds at least a certain threshold value c. That is, the following is true: The threshold value c can be determined as the average concordance index.

$$\underline{c} = \frac{1}{M(M - 1)} \times \sum_{\substack{k=1 \\ \text{and } k \neq l}}^{M} \sum_{\substack{l=1 \\ \text{and } l \neq k}}^{M} c_{kl}.$$

Based on the threshold value, the concordance dominance matrix **F** is determined as follows:

$$f_{kl} = 1, \quad \text{if } c_{kl} \geq \underline{c},$$
$$f_{kl} = 0, \quad \text{if } c_{kl} < \underline{c}.$$

Similarly, the discordance dominance matrix **G** is defined by using a threshold value d, where d is defined as follows:

$$\underline{d} = \frac{1}{M(M - 1)} \sum_{\substack{k=1 \\ \text{and } k \neq l}}^{M} \sum_{\substack{l=1 \\ \text{and } l \neq k}}^{M} d_{kl}. \qquad g_{kl} = 1, \text{ if } d_{kl} \geq \underline{d}, \quad g_{kl} = 0, \text{ if } d_{kl} < \underline{d}.$$

Step 6. Determine the Aggregate Dominance Matrix
The elements of the aggregate dominance matrix E are defined as $ekl = fkl \times gkl$.
Step 7. Eliminate the Less Favorable Alternatives
From the aggregate dominance matrix, we could get a partial-preference ordering of the alternatives. If $e_{kl}= 1$, then this means that A_k is preferred to A_l by using both concordance and discordance criteria.
If any column of the aggregate dominance matrix has at least one element equal to 1, this column is *"ELECTRE ally"* dominated by the corresponding row. [6].

2. CASE STUDY
There are a number of factors or drivers that influence the selection of an assembly system. But we consider that four different factors to evaluate our flexible assembly line. These are in the following.
Production rate. Higher rates are obtainable with systems that have multiple assembly stations. Also dependent on size, weight of parts and complexity of assembly operations needed, although the latter is heavily influenced by design
Capital cost of assembly system. System costs range from a few thousand pounds to many millions of pounds, depending on the degree of automation and number of parts to be assembled.
System operating costs. Costs associated with the day-to-day running of the system chosen. This can be substantial if manually centred, but less so with automated systems

Labour cost. availability and skill. These are very dependent on geographical location. cost of labour per assembly.

To evaluate the most appropriate assembly system we generate decision matrix which include factors for each alternative. There are four factors to decide the most appropriate alternative between three alternatives. Numbers which is defined in each column are interested in production rate(%), capital cost of assembly system(million \$), system operating costs(million \$) and labour cost(million \$) respectively. $A_{ij}=\begin{bmatrix} 85 & 40 & 4 & 15 \\ 90 & 35 & 3 & 20 \\ 85 & 30 & 3 & 15 \end{bmatrix}$

Number of components in the assembly. DFA aims to reduce the number of components in an assembly design by identifying redundancy and consolidation of parts where possible; however, there still remains a strong relationship between part count and cost. Factors weights are W_1: 0,20 W_2:0,35 W_3:0,40 W_4:0,05 respectively. The normalized matrix **X** and the weighted matrix denoted as **Y** are as follows

$$X=\begin{bmatrix} 0{,}5660 & 0{,}65541 & 0{,}6861 & 0{,}5145 \\ 0{,}5993 & 0{,}57348 & 0{,}5145 & 0{,}6860 \\ 0{,}5660 & 0{,}49156 & 0{,}5145 & 0{,}5145 \end{bmatrix} \quad Y=\begin{bmatrix} 0{,}1132 & 0{,}22939 & 0{,}27444 & 0{,}02572 \\ 0{,}11986 & 0{,}20071 & 0{,}2058 & 0{,}0343 \\ 0{,}1132 & 0{,}17204 & 0{,}2058 & 0{,}02572 \end{bmatrix}$$

Concordance and Discordance Matrices are calculated and we show results in the following matrixes.

$$C=\begin{bmatrix} - & 0{,}20 & 1 \\ 0{,}25 & - & 0{,}95 \\ 0{,}25 & 0{,}40 & - \end{bmatrix} \qquad D=\begin{bmatrix} - & 1 & 0 \\ 1 & - & 02992 \\ 0{,}270381 & 1 & - \end{bmatrix}$$

Based on the threshold value, the concordance dominance matrix **F** is determined , Similarly, the discordance dominance matrix **G** is defined by using a threshold value *d*. The elements of the aggregate dominance matrix is **E=** $\begin{bmatrix} - & 0 & 1 \\ 1 & - & 1 \\ 0 & 1 & - \end{bmatrix}$

This means that Second assembly system is preferred to the others.

3. CONCLUSION

There are number of factors or drivers that influence the selection of an assembly system. The main issues include such as labour cost, availability and skill, geographical location, production quantity, production rate, joining methods employed, capital cost of assembly system, system costs range, number of components in the assembly etc. But we have used four factors for selection assembly system. We have evaluated which assembly system is more appropriate for company using one of the Electre which is one of the Multi-attribute Utility Theory (MAUT) methods .

4. REFERENCES

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