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FUZZY RANKING METHODS OF FACILITY LAYOUT ALTERNATIVES UNDER MANUFACTURING ENVIRONMENT

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Abstract Most of the facility layout models found in the literature are unable to generate large number of alternatives. In this paper a constructional algorithm for facility layout under manufacturing environment is developed to generate a set of alternative layouts by varying the design parameters in order to minimize flow cost, dead space and minimum required area for layout. One of the real difficulties of facilities layout planning is the ranking of layout from a set of alternatives according to decision-makers choice because of the conflicting nature of the evaluating parameters. In this paper, Fuzzy Multi-Criteria Decision-making methodology is adopted to rank the alternatives generated. The suggested procedure is coded as a computer program in Turbo C language that runs under the Microsoft disc operating system. The proposed methodology is compared with the existing ranking methods. The experimental result with test problem is illustrated with encouraging results under heavy manufacturing environment.

Key words: Facility layout, Fuzzy, Multi-criteria decision making, Ranking, flow cost

INTRODUCTION

One of the prime opportunities of making a cost effective manufacturing system is the realization and development of accurate decision-making system about planning for facilities layout. The facility layout problem deals with arrangements of machines within a facility with respect to optimizing flow cost. The examples of such layout algorithms are ALDEP, CORELAP, CRAFT, COFAD, and PLANET etc [Francis and White, 1992]. Very less work has been done on the development of machine layout and alternatives generation [Deb et al, 2001]. The existing technique uses two valuable tools for the organization of data problems, the from-to-chart and the relationship chart. The body of the chart contains the quantitative flow of materials from one department to another. A relationship chart is used to indicate the qualitative relationships between two departments using a matrix structure [Tompkins and White, 1980][Apple, 1977]. The relationships are represented by set of letters like A, E, I, O, U and X with fixed rating specifying how important it is that the two particular machine blocks or departments are closing together or adjacent. Somebody who is knowledgeable about the facility subjectively decides these relationships. Plant layout problem has also been formulated using quadratic assignment and mixed integer programming. It has been proved that machine layout problems fall in the class of NP-hard solution. Heuristic algorithm falls to the class of construction type, improvement type, and hybrid construction/improvement methods. All these categories have strength and weakness [Heragu and Kusiak, 1990] have designed a knowledge-based system to solve machine layout problem under flexible manufacturing system. M. M. D. Hassan [1994] has presented a formulation of machine layout through optimization procedure. All these approaches do not satisfy the desirability of the plant managers. Hence an improved construction algorithm is required to generate a set of alternative layouts that can be presented to the decision makers for their choice. In this paper a multi-criteria objective function is proposed to generate set of alternative layouts by varying the weights of the criteria flow cost, dead space and minimum area required for layout [Deb et al. 2001]. The evaluating parameters of the alternative layouts are conflicting in nature. They are related inversely to each other i.e. FC decreasing with the increase of DS or MRAL. A multi-criteria decision-making is very effective under such situation to aggregate the overall performance of the system. The contribution of each parameter is standardized with respect to other with the help of a designed scale and the final rating is obtained to rank the alternatives. Decision makers are asked to assign their preference as per the designed rating scale within [0,10] in the level of linguistic variable as [very low, low, medium, high,

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very high]. The universe of discourse is considered in the range of lower and upper limit values of the evaluating parameters. The membership function of fuzzy set considers the degree of association of the linguistic variable in the rating scale. The aggregation becomes perfect with the use of fuzzy set theory in evaluating the overall performance of a system governed by multiple criteria. In general practice the ranking of alternatives is done through normalized and standardized methods, which fails to consider the interdependency while evaluating the overall ranking value. Thus fuzzy multiple criteria decision-making methodology would be very effective in evaluating the ranking of alternative of layouts generated by using the proposed constructional approach.

FUZZY SET AND DECISION MAKING

A fuzzy set can be thought of a class of concepts/objects in which no well-defined boundary exists about the concepts/objects that belong to the class and those which do not belong. Formally, if X={x} is a set of objects, then the fuzzy set A on X is defined by its membership function $f_A(x)$ which assigns to each element x ε X a real number in the interval { 0, 1 }which represents the grade of membership of x in A or the degree to which x belongs to A. Thus A can be written as:

$A=\{ (f_A(x)/x)|x \varepsilon X \};X\rightarrow[0,1]$

Fuzzy linguistic variables

Linguistic variables are words in natural language, while numerical variables use number as values. Since words are usually less precise than numbers, linguistic variables provide a method to characterize complex system that are ill-structured to be described in traditional quantitative terms. A linguistic variable is defined by the name of the variable x and the set term S (x) of the linguistic values of x with each value being a fuzzy number defined on U. For example if sound is linguistic variable, its term set S(sound)={very high, high, medium, low, very low}, where each term is characterized by a fuzzy set in a universe of discourse U=[0, 60], as shown in Figure 1(a). The figure shows that 35 db belongs to the linguistic variables {medium, high} with membership values of {0.38, 0.69} respectively. Using the maximum value to find the fuzzy set level that this sound level 35 db belongs to the fuzzy set high with a membership value of 0.69.

Fuzzy decision making system

The four components of the FDMS are (1) In fuzzification interface (FI) the different inputs and outputs variables are measured and converted into natural language, (2)In knowledge base interface (KBI) the membership functions of the input variables are decided by the experts based on their Knowledge of the system, (3) In decision rules base interface (RBI) the experts decision-making ability is simulated based on a fuzzy concept. The connective 'and' is implemented as

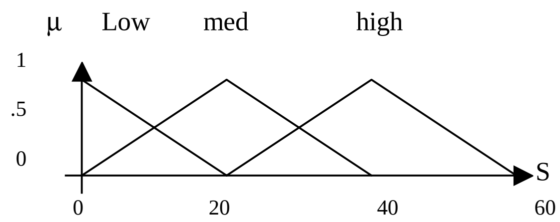

Fig .1(a) Membership function of Sound

a fuzzy conjunction in a Cartesian product space in which the input variables take in their respective universe of discourses. The minimum operator is used and the decision rules are in the form of IF-THEN, and (4) in defuzzification interface (DFI) the fuzzy outputs are determined by center of area (COA) method.

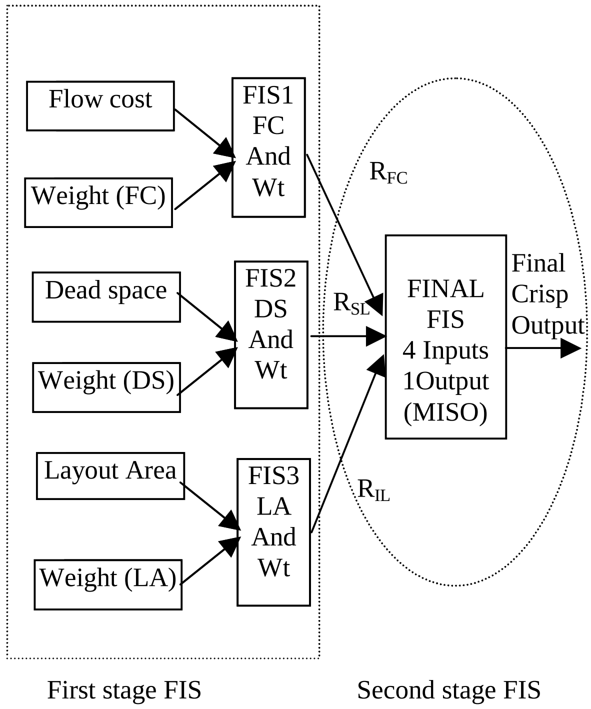

Fig. 2(a). Two-stage Fuzzy Inference System for Ranking facility layout alternatives

ANALYTICAL HEIRARCHY PROCESS

The AHP is a decision making tool for dealing with complex, ill structured and multiple attributes decision problem. It helps in evaluating multiple attribute alternatives when subjective assessments of qualitative factors are integrated with quantitative factors. L. Saaty developed it during 1970s. Since its initial development, AHP has been used in a wide variety of decision areas, including manufacturing and production systems [Dweri, 1999]. The traditional decision making approaches consider only the quantitative factors, failing to recognize the many importance qualitative factors such as environmental link, supervision link in a manufacturing system. Moreover traditional layout decision overlooks the problem of inconsistencies of designers. The AHP uses a nine-point scale defined to get intensity importance factor (a_{ij}) as: 1- equal importance, 3-moderate importance, 5-strong importance, 7-very strong importance, and 9-extreme importance. The even numbers 2, 4, 6 and 8 are for compromise, and the reciprocals show the inverse pair wise comparisons. These numbers represent the weight factors (priorities) of the reasons involved in the decision making process. The intensity importance of factor i over factor j is equal to reciprocal of intensity importance of factor j over factor i.

GENERATING ALTERNATIVE LAYOUTS

The procedure determines the optimum location of facilities depending on a placement order. The procedure needs the computations of decision variables like coordinates of the diagonal , input and output points of the blocks. The procedure consists of mainly two steps as

Selection procedure

In this step the sequence at which the facilities are to be placed is calculated fron the flow matrix and other qualitative parameters dictating the importances of adjacency. The first facility to be selected for placement is the one which has the maxium value of flow or interactions with the other machines. If the flow matrix is unsymetrical i.e. two way flow then total flow value of the ith facility with other facilities:

$$f_{ij} \neq f_{ji} \quad \text{and} \; f_{ij} = 0 \quad \text{for } i = j$$

$$F_i = \sum_{j=1}^{m} (f_{ij} + f_{ji}) \quad \forall \quad i, j = 1, 2, ...m.$$

$$F_k = \max\{F_i\} \qquad \forall \quad i = 1, 2, ...m$$

The first facility to be selected for placement will be the facility K for which value of flow is maximum. Next facility to be selected is the one which has the maximum flow value with the facility already selected and the procss is repeated for all other facilities to include them in the sequencial placement.order. It is similar to
PLANET (Apple and Deisenroth, 1972), COFAD(Tomkin and Reed, 1976) .

Placement procedure

The first block is placed at the center of a plane continuum horizontally (may be vertically). The method for the placement of next blocks is to evaluate the value of objective function at each candidate point on the already placed block for two configurations, two rotations and three styles i.e. twelve possible ways as shown in figure no.5. Searching is carried out through all candidate points on the four edges of the block for that particular combination of candidate point, configuration, orientation and style for which the objective function value is minimum and the block is placed. The process is repeated for the remaining facilities.

Steps of algorithm

Step1.Find the selection order of machines for their placement in open field.
Step2.Locate the first block at the center horizontally.
Step3.Select the next block for placement according to placement order.
Step4.Select the candidate point and check the feasible quarter. If not feasible go to step 7, else go to next step.
Step5.Locate the block according to placement possibilities and check for non-overlapping. If not satisfied repeat next possible placement , else go to step 6.
Step6.Calculate the value of objective function ,if it is better than previous update Configuration and objective function value. Go to step 5 for next searching other possibilities at the candidate point.
Step7.Select next candidate point If all candidate points of the selected block are considered, go to step 8, otherwise go tostep 4.
Step8.Select the next block. If all blocks are selected go to step 9 else go to 3.
Step9.Locate the block which provide the best value of objective function.

Multiple objective function

Malakooti (1989) analysed the use of weighting method to handle multiple objectives in the facility layout. Therefore, the present problem can be modelled as the minimizing

$$Z=W_1* FC+W_2*DS+W_3*MRAL$$

where $W_1+W_2+W_3=1$

By varying the weights W_1, W_2 and W_3 systematically it is possible to generate several alternative non-inferior solutions using the propopsed algorithm. Since there is no gurantee that the algorithm would generate optimal solutions, it is essential to investigate the set of Pareto-optimal points and select a solution of decision-makers' preference. By investigating the pareto optimal points, the decision makers can have only a set of preferable solution of layout structure after eliminating the inferior solutions. Many important decisions are based on the preferences of group of facility planner. It would be necessary to focus on specific type of problems.

Pareto optimality of ranking

An alternative is dominated if there exists some other alternative that is at least as desirable to every individual and more desirable for at least one individual. The alternatives that are not dominated are referred to as the pareto optimal set. The pareto optimal set north east frontier of the available alternatives when plotted according to their desirabilityof any pair of individuals. The shortcoming of the Pareto rule is that it does not provide a complete ranking of the alternatives; there may be many pareto optimal alternatives. Every individual is benefited by moving from a non-pareto to a pareto to a pareto optimal alternative.

S D method(Z-SCORE)

The multi-objective evaluations of alternatives with or without incorporating personal preference is done by transforming scores according to how the scores turn out for the whole set of alternatives. The first transformation is to standardize scores based on mean and standard deviation of the objective values. Each score is transformed into is so called Z-score, which is the number of standard deviation that the score differs from the mean. Thus a layout's score for participation is

$Z_{FC}=(FC-FC_{mean}) / FC_{sd}$

This approach is appropriate when scores would be normally distributed. Once the Z-scores for the attributes have been calculated, the value score for the i th alternative would be

$Z(i)_{total}=W_1*Z(i)_{FC}+W_2*Z(i)_{DS}+W_3*Z(i)_{MRAL}$

The lowest value score is ranked first and subsequently the others.

Normalized method(N-SCORE)

The second way of transform the attributes would be to normalize the scores so that the best alternative on each attribute received a score of 100 and the worst 0. Thus the normalized score for participation would be

$N_{FC}=(FC-FC_{mean}) / (FC_{max} - FC_{min})$ where N_{FC} is the transformed normalized value of score. Thus, the total value score for the alternative i would be

$N(i)_{total}= W_1*N(i)_{FC}+W_2*N(i)_{DS}+W_3*N(i)_{MRAL}$

The alternative having the lowest value of N is ranked first and subsequently the others.

PROPOSED RANKING METHODOLOGY

The evaluation of the alternative depends on the criteria (1) Flow cost, (2) Dead space and (3) MRAL.

An efficient layout should have a low flow cost, dead space and MRAL. The evaluating parameters are taken as the input of the fuzzy inference system [Zimmerman, 1987] within the universe of discourse in the range of lower and upper limit of the input variables. The input variables are rated in a designed scale as [VL, L, M, H, VH]. The output of the FIS is the crisp score within a designed scale of [0,10] . The relative priorities of each criteria is computed bu using the Saaty's analytical hierachy process[1970]. The weight of each crateria for all the alternatives are determined. The rule base contains a list of rules as follows

IF (FC) is (H) and (WT) is (H) then (score) is (H) etc. Thus if $W=[w_{ij}]$ is the weight matrix and $V=[v_{ij}]$ is the value matrix for i=1,2,….n and j=1,2,…m; where n is the number of alternatives and m is the number of criteria then there are 25 rules for each set of rule list i.e. weight versus FC, DS and MRAL. The two stage fuzzy inference system proposed in this paper for ranking altrnatives is shown in figure 2(a). If S_{ij} is the output score

of alternative i for criteria j , then the aggregated score of alternative [i] is given as

$S_i=1 / m\sum S_{ij} \quad \forall$ i =1,2,…n; j=1,2,….m.

The value of S_i are arranged in decending order and the ranking order of alternatives are obtained i.e. the alternative having the highest aggregated score is ranked as number 1.

APPLICABILITY OF METHODOLOGY

The applicability of the problem is demonstrated wih the help of an example problem having 6 machines and 30 moves. The machine specification and flow matrix of the

Table 1: Machine dimensions and P/D points

M	1	2	3	4	5	6
L	60	30	120	48	72	54
W	30	30	30	36	24	36
P	0,15	0,15	60,0	24,0	0,12	27,0
D	60,15	30,15	60,30	24,0	36,0	0,18

Table 2: Flow values of moves

M	M1	M2	M3	M4	M5	M6
M1	0	1	2	1	2	3
M2	5	0	1	2	1	2
M3	2	3	0	3	2	1
M4	4	0	0	0	1	2
M5	1	2	0	5	0	1
M6	0	2	0	2	10	0

Table 3: Values of FC, DS and MRAL (A=Alternative number, W_3=0)

A	W_1	W_2	FC	DS	MRAL
1	1	0	6059	1856	3325
2	.9	.1	5823	1122	2591
3	.8	.2	6263	1821	3290
4	.6	.4	6812	502	1971
5	.5	.5	6901	407	1876
6	.4	.6	8512	259	1728
7	.2	.8	8137	329	1798
8	0	1	11154	556	2025

Table 4: Relative weights of criteria

A	FC(W_{i1})	DS(W_{i2})	MRAL(E_{i3})
1	0.529	0.218	0.253
2	0.436	0.376	0.188
3	0.617	0.203	0.180
4	0.398	0.467	0.135
5	0.524	0.253	0.223
6	0.587	0.217	0.196
7	0.365	0.249	0.326
8	0.511	0.337	0.152

Table 5: Crisp values of FIS output Score (S_{ij}) and Ranking of alternatives

A	FC (S_{i1})	DS (S_{i2})	MRAL S_{i3})	Fuzzy Score	Ranking Order
1	7.08	4.00	3.60	4.89	3
2	6.56	3.70	1.97	4.08	8
3	6.98	4.00	3.19	4.72	4
4	4.71	5.94	3.08	4.57	7
5	5.58	4.85	5.09	5.17	2
6	5.01	5.52	5.52	5.35	*1
7	3.28	5.21	5.77	4.71	5
8	6.00	4.40	3.37	4.59	6

Table 6: Ranking by Z, N and Fuzzy method

A	Z-value	N-value	ZR	NR	FR
1	0.39	0.52	6	6	3
2	-0.28	0.27	2	5	8
3	0.42	0.53	7	7	4
4	-0.48	0.16	2	2	7
5	-0.53	0.14	*1	*1	2
6	-0.17	0.25	5	4	*1
7	-0.22	0.23	4	3	5
8	0.87	0.59	8	8	6

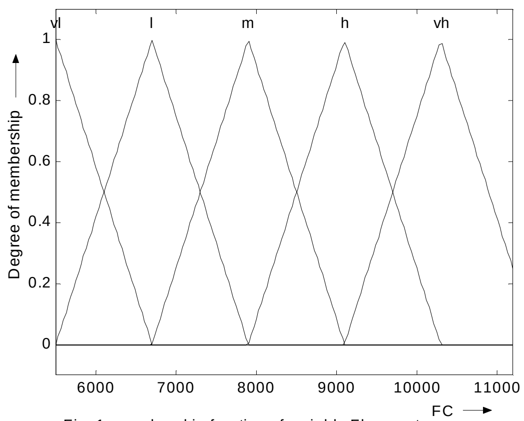

Fig. 1. membership function of variable Flow cost

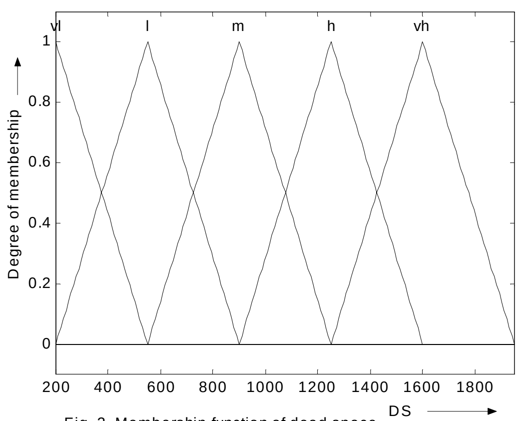

Fig. 2. Membership function of dead space

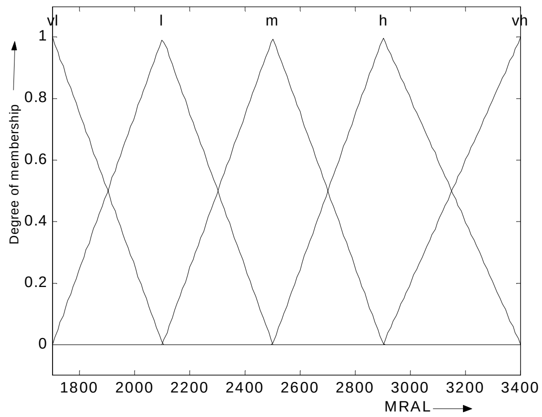

Fig.3. Membership function of variable MRAL.

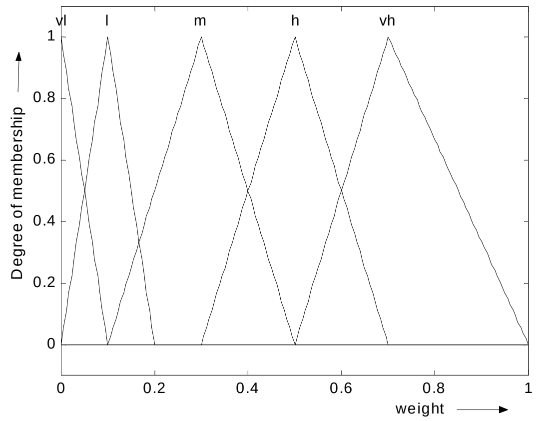

Fig. 4. Membership function of variable weight

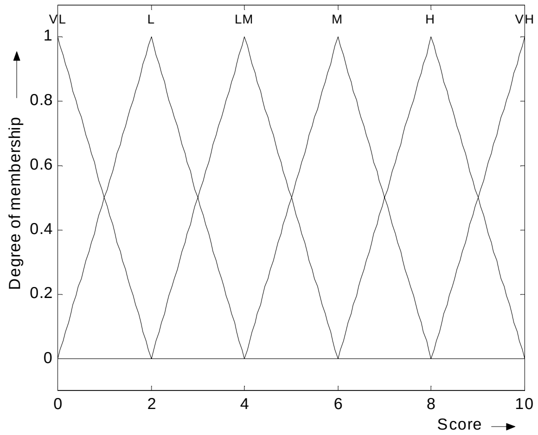

Fig. 5. Membership function of output score

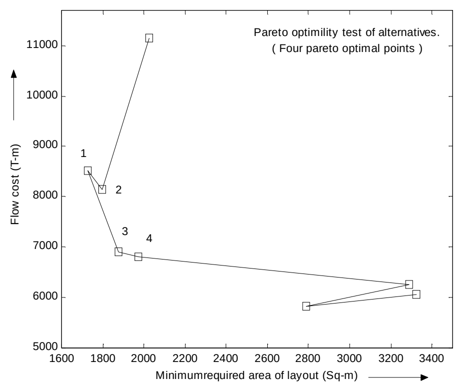

Fig .6 Pareto optimal points of alternative layouts

problem is shown in table 1 and 2 respectively. The values of FC, DS and MRAL of the alternatives obtained by chainging the weights of he objective function are shown in table 3. The weight of the three criteria(W_{ij}) for all the alternatives obtained by applying Saaty's 9 point scale of analytical hierarchy process are shown in table 4. The membership functions of the input variables FC, DS, MRAL and output variable score are shown in figure 1, 2, 3 and 4 respectively. Figure 5 shows the membership function of variable weigth. The crisp output of the three set of FIS and the aggregated value of score of the alternatives are shown in table 5. The pareto analysis of the alternatives with test results shown in table 3 are shown in figure 6. Four pareto optimal points are found following S-W rule to satisfy the desirablity of the plant manager. The pareto optimility test can only produce a set of favourable alternatives from a number of alternatives. The value of Z-score, N-score and fuzzy score of the alternatives are represented in table 6 showing the best alternatine(*) under each approach.

DISCUSSION AND CONCLUSION

The paper presents a distinct methodology of selecting best alternative layout or ranking them from a set of non-inferior solutions obtained by varying the weights of the multi-objective function. The methodology uses the fuzzy decision making making system and analytical hierarchy process. The inconsistencies of the decision-makers choice are eliminated by by considering the relative prioroties of one criteria over other.The proposed methodology is better than the Z-score and N-score methods because it considers the degee of association of one criteria over other as assigned by the decisin makers.

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