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DESIGN OF MULTI- OBJECTIVE CELLULAR MANUFACTURING SYSTEM

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ABSTRACT

Cellular manufacturing system design is a multiple objective task with goals such as minimization of investment in machines, operating costs, material handling cost, machine relocation cost, set-up time, inventories, sum of investments and maximization of resource utilization, output, etc. These various costs may be flexible with vagueness in their values. Due to imprecise nature of the parameters, the problem becomes fuzzy. The concept of fuzzy set theory may be applied to solve the problem. In this paper, the additive and weighted additive operator has been used to aggregate fuzzy membership functions corresponding to fuzzy sets for fuzzy goals. This aggregation gives the overall achievement function and model takes the linear from. A preference or interactive fuzzy model has also been provided to get the presented to illustrate the methodology.

Key words: Cellular manufacturing system, multi-objective cellular manufacturing system design, fuzzy goals, Group technology

1. INTRODUCTION

Group technology (GT) is a manufacturing philosophy where main idea is to capitalize on similar & recurrent activities. Heyer et al discussed the philosophy of Group technology with broad applicability, potentially attaching all areas of a manufacturing organization. (1). One specific application of GT is cellular manufacturing (CM). CM involves processing collections of similar parts (part families) on dedicated cluster of dissimilar machines or manufacturing processes (cells). CM is currently the focus of considerable interest from practitioners and academics alike. This interest seems related both to the manufacturing industries struggling for survival and to the emergence of new technologies. One major international competitor, Japan, makes extensive use of CM in order to achieve just-in-time (JIT) manufacturing. Wemmerlor et al stated that in the last few years, there has been a tendency among U.S. and European manufactures to learn and copy successful Japanese strategies as a way to improve their own competitiveness. There is no question that CM represents a major technological innovation to most organization. (11).

The most important issue designing CMS is the decomposition of a manufacturing system into cells. This involves grouping parts based on similarity in design or processing requirements into part families and for each part family one machine cell is conceived. During recent years extensive research has been carried out in the area of CMS design. Various approaches such as heuristic, simulation, mathematical etc. have been attempted. Thompson states that since now a days the organization are being more and more complex, their most important tasks have become to manage uncertainty and vagueness (10). Shankar et al discussed different goals of cellular manufacturing systems as costs, time, capacity, demand are fuzzy in nature (9). Maghsud solimanpur et al presented a multi-objective integer programming model is constructed for the design of cellular manufacturing systems with independent cells. (5).

Kioon etal have designed a comprehensive multi-objective mixed integer mathematical programming model which considers cell formation problem (2). Mohammad Saidi et al have developed a multi-objective mixed integer model is presented that considers some real-world critical conditions same as costs of multi-period cell formation and production planning , human resource assignment to cells and balancing workload of cells(6). Mahdavi et al have developed fuzzy goal programming-based approach is used to solve a proposed multi-objective linear programming model and simultaneously handle two important problems in cellular manufacturing systems, viz. cell formation and layout design(12). In this paper an interactive model for multi objective cellular manufacturing design (MOCMSD) using fuzzy sets is presented.

2. MODEL FORMULATION (Preference or Interactive model for MOCMSD Problem)

A linear model for multi-objective cellular manufacturing system design (MOCMSD) problem having 'k' objective functions in 'n' variables subject to 'm' constraints can be stated as:

Optimize $f(x) = \{f_1(x), f_2(x), \text{------------------------------}, f_k(x)\}$

Subject to $g_1(x) \leq b_1$

$g_2(x) \leq b_2$

$g_m(x) \leq b_m$

$$x = (x_1, x_2 \text{-------------------------}, x_n) \geq o \text{ --------------------} \qquad (2.1)$$

Where $f_1(x), f_2(x)$, --------- $f_k(x)$ denote various costs and $g_1(x), g_2(x)$, ---------, $g_m(x)$ are the constraints related to the manufacturing system.

Actually the increase/decrease in any one of the objective function will affect the others. In MOCMSD problem, the concept of an overall global optima solution which in turn, depends on the decision maker's preference

Assigning aspiration level vector $P= p_1, p_2,$ ----------- p_k to the k objectives $f_1(x)$, (i = 1, 2, ----------, k) which give rise to the following problem known as MOCMSD problem, the multiple objective goal model can be stated as:

Determine x_{mskp}

Subject to $f_1(x) \leq p_{1,}$

$f_2(x) \leq p_{2,}$

$f_k(x) \leq p_{k1}$

$g_1(x) \leq b_1$

$g_2(x) \leq b_2$

$g_m(x) \leq b_{m,}$

$x \geq 0$ -------------- (2.2)

In real situation all goals are not rigid. Sometimes some goals may be fuzzy or some rigid. Therefore it is more realistic to assign fuzzy goals by allowing some flexibility in the hand side of some goals and some constraints.

Now the fuzzified version of the model (2.2) is described as

Determine X_{mskp}

Subject to

$f_1(x) \leq p_{1,}$

$f_2(x) \leq p_{2,}$

$f_1(x) \leq p_{1,}$

$f_{1+1}(x) \leq p_{1+1,}$`

$f_k(x) \leq p_{k1}$

$g_1(x) \leq b_1$

$g_2(x) \leq b_2$

$g_r(x) \leq b_r$

$g_{r+1}(x) \leq b_{r+1}$

$g_m(x) \leq b_{m1}$

$x \geq 0$ ------------- (2.3)

Where, the wavy symbol, (~) stands for fuzzification (approximation).

The model (2.3) cannot be solved in the present form. Therefore we defuzzify this model with the help of linear membership function using the concept of fuzzy set theory. (ref.8).

We allow each fuzzy element pi of vector P to go above pi say to pi and each fuzzy element bj of vector B to go above b1 say to bj. Here αi_i & β_j are tolerance limits.

Membership function corresponding to i th fuzzy goal $f_i(x) \le p_i$ may be defined by

$$\mu f_1(x) = \frac{p_1 - f_1(x)}{\alpha_1} \quad , \qquad i = 1, 2,3 \text{ -----------------}, l$$

and corresponding to the j[th] fuzzy constraint $g_j(x) \le b_j$ by

$$\mu g_1(x) = \frac{b_1 - g_1(x)}{\beta_j} \quad , \qquad j = 1, 2, 3 \text{ -----------------}, r$$

The overall achievement function is taken as algebraic sum of all membership functions, which may be represented as:

$$V(\mu) = \sum_{i=1}^{l} uf_1(x) + \sum_{j=1}^{r} ug_j(x)$$

2.1 Simple Additive Model for MOCMSD problem

Thus the additive fuzzy linear programming model of CMS design Problem using additive operator can be given by

$$\text{Max.} \quad V(\mu) = \sum_{i=1}^{l} uf_1(x) + \sum_{j=1}^{r} ug_j(x)$$

Subject to: $\alpha_1 \mu f_1(x) + f_j(x) = p_i;$ i=1,2--------------,l

$\beta_j v g_j(x) + g_j(x) = b_i;$ j=1,2--------------,r

$f_{1+1}(x) \le p_{1+1},$

$f_k(x) \le p_{k1}$

$g_{r+1}(x) \le b_{r+1}$

$g_{r+2}(x) \le b_{r+2}$

$g_m(x) \le b_{m1}$

$x \ge 0$ ------------- (2.4)

2.2. Normalized Weighted Additive Fuzzy model form MOCMSD problem:

In real life all objective are not of same importance i.e. they are of varying utilities so the normalized weights (w_i>0, $\sum w_i = 1$) may be assigned to the membership functions for determining the overall achievement function.

Therefore the Normalized Weighted Additive Fuzzy Model of MOCMSD problem is stated as:

$$\text{Max.} \quad V(\mu) = \sum_{i=1}^{l} w_i uf_1(x) + \sum_{j=1}^{r} w_j ug_j(x)$$

Where w_1(i=1,2,-------------,l) & w_j (j=1,2,------------,r)are different normalized weights.

Subject to: $\alpha_1 \mu f_1(x) + f_j(x) = p_i$; i=1, 2--------------,l

$\beta_j \nu g_j(x) + g_j(x) = b_i$; j=1, 2--------------,r

$f_{1+1}(x) \leq p_{1+1,}$

$f_k(x) \leq p_{k1}$

$g_{r+1}(x) \leq b_{r+1}$

$g_{r+2}(x) \leq b_{r+2}$

$g_m(x) \leq b_{m1}$

$X \geq 0$ ------------- (2.5)

The weighted additive model reflects that the objectives and/or constraints are of varying importance. This model is widely used in multi objective programming to reflect the relative importance of objectives and/or constraints. Relative importance of criteria may be expressed in terms of weight or priority. Decision maker may use the methods proposed by Satty (ref.4) & Rao (ref.3)

2.3. Interactive Fuzzy Model for MOCMSD problem:

(a)Change in Normalized weights

Max. $V(\mu) = \sum_{i=1}^{l} w_i u f_1(x) + \sum_{j=1}^{r} w_j u g_j(x)$

Where w_1(i=1,2,-------------,l) & w_j (j=1,2,------------,r)are different normalized weights.

Subject to: $\alpha_1 \mu f_1(x) + f_j(x) = p_i$; i=1,2--------------,l

$\beta_j \nu g_j(x) + g_j(x) = b_i$; j=1,2--------------,r

$f_{1+1}(x) \leq p_{1+1,}$

$f_k(x) \leq p_{k1}$

$g_{r+1}(x) \leq b_{r+1}$

$g_{r+2}(x) \leq b_{r+2}$

$g_m(x) \leq b_{m1}$

$x \geq 0$ ------------- (2.6)

(b)Change in Aspiration level:

Max. $V(\mu) = \sum_{i=1}^{l} w_1 u f_1(x) + \sum_{j=1}^{r} w_2 u g_j(x)$

Subject to: $\alpha_1 \mu f_1(x) + f_j(x) = p_i*$, i=1,2--------------,l

$\beta_j \nu g_j(x) + g_j(x) = b_i*$, j=1,2--------------,r

$f_{1+1}(x) \leq p_{1+1},$

$f_k(x) \leq p_{k1}$
$g_{r+1}(x) \leq b_{r+1}$

$g_{r+2}(x) \leq b_{r+2}$

$g_m(x) \leq b_{m1}$
$x \geq 0$ ------------- (2.7)

(c) Change in Normalized weights &.Aspiration levels both:

$$\text{Max. } V(\mu) = \sum_{i=1}^{l} w_1 u f_1(x) + \sum_{j=1}^{r} w_j u g_j(x)$$

Where w_1(i=1,2,-------------,l) & w_j (j=1,2,------------,r)are different normalized weights.

Subject to: $\alpha_1 \mu f_1(x) + f_j(x) = p_i^*,$ i=1,2--------------,l
$\beta_j v g_j(x) + g_j(x) = b_i^*,$ j=1,2--------------,r

$f_{1+1}(x) < p_{1+1},$

$f_k(x) < p_{k1}$
$g_{r+1}(x) < b_{r+1}$
$g_{r+2}(x) < b_{r+2}$

$g_m(x) < b_{m1}$
$x > 0$ ------------- (2.8)

The interactive fuzzy approach is a very systematic process involving alternate stages of calculation and decisions, which helps acquiring deep insight into the MOCMSD problem. This provides acceptable solution to the MOCMSD problem in fuzzy environment. Using the above techniques, the most compromising solutions are obtained by having a direct interaction with the decision maker (DM). The DM indicates his satisfaction over the current levels of achievement function and the consequent objective levels of achievement function to the current solution. He is then asked how much could to be the value of objectives which have been most satisfactorily achieved. Based on his option, appropriate changes are brought in the aspiration levels of such objectives and membership function of fuzzy set corresponding to these objectives are defined a fresh. This results in a fresh model to be solved and a compromise solution is obtained. If the DM is not fully satisfied with the solution, another solution is obtained again by interacting with the DM, i.e the interactive system will continue till the most satisfactory solution is achieved.

3.1 Model Environment of C.M.S. Design

In the mathematical programming model for CMS design, (ref.2), all parameters have been considered rigid. But practically this is not feasible. Therefore we have considered some parameters like investment in machine and manufacturing budget as flexible. The model formulated in fuzzy form is as follows:

$$f_1(x) = \sum_{mf} C_m Z_{mf} < p_1$$

$$g_1(x) = \sum d_k X_{mskp} C_{mskp} < B$$

$$g_2(x) = \sum_p Y_{kp} = 1 \qquad \forall k$$

$$g_3(x) = \sum_m \alpha_{mskp} x_{mskp} = a_{skp} y_{kp} \qquad \forall s, k, p$$

$$g_4(x) = \sum_{ksp} (\beta_k d_k \alpha) x_{mskp} t_{mskp} < b_m Z_{mf} \quad \forall m, f \qquad \text{--------------} \quad (3,1)$$

Where C_m = Cost per machine of type m

Z_{mf} = Number of machine of type m for processing part. family f.

K = Part type (k = 1,2,3,-------, k)

p = Process plan used (p = 1,2,3,-------, p)

Y_{kp} = 1, if part k is manufactured using plan p.
= 0, otherwise

m = Machine types (m 1,2,3, ------, M)

S_k = Operation to be performed on part type k
(s= 1,2,3,----------, S_k)

α_{mskp} = 1, if operation s has to be performed on machine m for combination kp.
= 0, otherwise

a_{skp} = 1, if operation s has to be performed for combination kp

X_{mskp} = 1, if machine m is used to perform operation s for Combination kp.

β_{kf} = 1, if part k is a member of part family f.
= 0, otherwise.

d_k = demand of part type k.

t_{mskp} = Unit processing time if operation s is performed on machine m for kp combination.

b_m = Capacity of machine type m

C_{mskp} = Unit processing cost if operation s is performed on Machine m for kp combination
= α, if such an operation cannot be performed on machine m.

B = Operating budget.

3.2 Sample Problem of CMS Design

A company manufactures four part types. Using a coding and classification method, the first two parts have been grouped into the first part family and the third and the fourth parts into the second family. The parts can be processed on three types of machines. Alternative process plans have been developed for all parts. The purchase costs for three machine types are \$100, \$250 and \$300, respectively and the operating budget available is \$350. The unit processing costs and time data for all parts and the alternative process plans are given in table 1. Determine the cell configuration and the number of machines of each type using the model developed to minimize the total investment cost in machine.

Table-1

M/C Types		**m=1**			**m2**			**m3**			
Operation Part		**S=1**	**S=2**	**S=3**	**S=1**	**S=2**	**S=3**	**S=1**	**S=2**	**S=3**	**Demand**
K=1	P=1	5.3				3.5		7.2	4.3		10
	P=2			8.8		9.8	7.7		7.9		
K=2	P=1	3.4		10.9		7.8	8.9	4.3	7.7		10
	P=2			6.5		3.3	6.6		2.3		
K=3	P=1	2.2				3.3		2.2	4.4		10
	P=2			11.7		1.2	8.8		2.4		
	P=3	8.1		7.4		5.9	9.5	9.2	3.10		10
K=4	P=1	1.2		3.5		2.3	2.6	2.1	2.4		
	P=2	9.7				9.8		8.9	10.9		10
CAPACITY			100			100			100		

On solving the problem using linear programming technique we get the following result
f(x) = 900.00 (investment in machine)

i) Cell-1: part family (part 1&2) is processed on m/c type 2&
m/c tu[e 2(1 mp.), m/c type 3(1 no.),
Cell-2: Part family 2(part 3&4) is processed on m/c type 1&
m/c type 1(1no.) m/c type 2(1 no.)

ii) Process plan selected for each part

Part 1 Plan 1

Part 2 Plan 2

Part 3 Plan 1

Part4 Plan 1

The fuzzy version of the above problem can be set as:

Determine X_{mskp}

Subject to $f_1(x)$ <900.00 {from simple Lp solution}

$g_1(x) <$ 350.00 {from the question}

$g_2(x) = 1$

$g_3(x) = a_{skp}\, y_{kp}$

$g_4(x) < b_m Z_{mf}$ -------------(3.2)

Now the problem is defuzzifed as follows:
The linear membership functions corresponding to these fuzzy goals are Defined as follows:

$$\mu f_1(x) = \frac{930 - f(x)}{90}$$

and $\mu g_1(x) = \dfrac{360 - f(x)}{70}$

Here $\alpha_1 = 90 and \beta_1 = 70, p_1^{'} = 930, b_1^{'} = 360$

The crisp model of the model (3.2) is stated as:

Max. V $(\mu) = w_1 \mu f_1(x) + w_2 \mu \; g_1(x)$

Subject to: 90 μ f_1 (X) + 100Z11 +100Z12 + 250Z21 + 250Z22 + 300Z31 + 300Z32 = 930
70 μ G_1(X)+30X1111+40X1121+80X1312+90X1321+50X1322+50X2211+80X2212+80X2221+30X2222+70X2312+90X2321+60X2322+20X3111+30X3121+30X3211+90X3212+70X3221+30X3222+20X1131+10X1133+20X1141+70X1142+70X1332+40X1333+50X1341+30X2231+20X2232+90X2233+30X2241+80X2242+80X2332+50X2333+60X2341+20X3131+20X3133+10X3141+90X3142+40X3232+100X3233+40X3241+90X3242 = 360

Y11+Y12=1
Y21+Y22=1
Y31+Y32+Y33=1
Y41+Y42=1
X1111+X3111-Y11=0
X1121+X3121-Y21=0
X1131+X3131-Y31=0
X1133+X3133-Y33=0
X1141+X3141-Y41=0
X1142+X3142-Y42=0
X2211+X3211-Y11=0
X2221+X3221-Y21=0
X2222+X3222-Y22=0
X2231+X3231-Y31=0
X2232+X3232-Y32=0
X2233+X3233-Y33=0
X2241+X3241-Y41=0
X2242+X3242-Y42=0
X1312+X2312-Y12=0
X1321+X2321-Y21=0
X1322+X2322-Y22=0
X1332+X2332-Y32=0
X1333+X2333-Y33=0
X1341+X2341-Y41=0
50X1111+30X1121+80X1312+100X1321+60X1322-100Z11 ≤0
30X2211+90X2212+70X2221+30X2222+70X2312+80X2321+60X2322-100Z21 ≤0
70X3111+40X3121+40X3211+70X3212+70X3221+20X3222-100Z31 ≤0
20X1131+80X1133+10X1141+90X1141+110X1332+70X1333+30X1341-100Z12 ≤0
30X2231+10X2232+50X2233+20X2241+90X2242+80X2332+90X2333+20X2341-100Z22 ≤0
20X3131+90X3133+20X3141+80X3142+40X3231+20X3232+30X3233+20X3241+100X3242-100Z32≤0 ----------- (3.3)

TABLE-2

W_1	W2	α	β	P_1	b_1	f(x)	g(x)
CHANGE IN NORMALIZED WEIGHTS							
0.1	0.9	90	70	930	360	900.03	256.4
0.4	0.6	90	70	930	360	850.80	260.6
CHANGE IN ASPIRATION LEVEL							
0.4	0.6	90	70	920	350	850.07	280.0
0.4	0.6	90	70	900	330	850.05	279.95
CHANGE IN NORMALIZED WEIGHTS & ASPIRATION LEVEL BOTH							
0.1	0.9	90	70	920	350	900.02	260.05
0.3	0.7	90	70	900	330	890.01	250.06

4. COMPARISON BETWEEN THE RESULTS

Initially the investment on machine f(x) = \$900 & budget g(x) = \$350. Solving the same problem using the proposed interactive model (2.6), (2.7),(2.8), we get different values of f(x) & g(x) by changing normalized weights, aspiration level & both respectively.

5. CONCLUSION

The interactive fuzzy MOCMSD problem is a learning process of the behavior, which was allows technological and psychological satisfaction to the DM. This proposal is a problem oriented and DM's dependent technique. The method is operational and computationally efficient. During the various iterations the DM may learn to recognize good solutions and relative important factors involving in the MOCMSD problem. The DM may be satisfied with the solution or he may want to modify some situations and/or change the original model. If satisfied the MOCMSD problem is considered to be solved. If not, the interactive system will continue till the most satisfactory solution is achieved.

REFERENCES

1. Heyer.N.L. and Wemmerlov.U, (1992) MRP/GT; A frame work for production planning and control of cellular manufacturing. Decision sciences 13:681.
2. Kioon, S.A., Bulgak, A.A. and Bektas, T., (2009) Integrated cellular manufacturing systems design with production planning and dynamic system reconfiguration, European Journal of Operational Research, Vol. 192, No. 2, pp. 414-428.
3. Rajamani.D.,Singh.N.andAneja.Y.P.(1990),Integrateddesignof cellular manufacturing systems in presence of alternative process plans, International Journal of Production Research, 28,1541-1554.
4. Mahdavi I , M.M. Mahdi Paydar , M. Solimanpur(2011) Solving a new mathematical model for cellular manufacturing system: A fuzzy goal programming approach, Iranian Journal of Operations Research Vol. 2, No. 2, 2011, pp. 35-47
5. Maghsud Solimanpur, Prem vrat and Ravi shankar (2004) A multi- objective approach to the design of cellular manufacturing systems, International Journal of Production Research, 01 april 2004, vol. 42, no. 7

6. Mohammad Saidi, Seyedeh Maryam Mirnezami (2011), Developing a Multi-objective Mathematical Model for Dynamic Cellular Manufacturing Systems Journal of Optimization in Industrial Engineering 7
7. Rao, J.R. and Nilima, Roy(1989). Fuzzy set theoretic approach to assigning weights to objectives in multi criteria decision making, Int. J. Systems. Sci.20, P.1381.
8. Saaty,T.L.(1978). Exploring the interface between hierarchies multiple objectives and fuzzy sets. Fuzzy sets and systems, 1,p.57.
9. Shanker.R and Vrat.P.,(1997), A Stochastic programming approach to cellular manufacturing system design. Pro. International conference on advances in mechanical and industrial engineering. UOR.
10. Thompson, J.D,(1997), Organization in Action (New York : MC.Graw-Hill)
11. Wemmerlor, U and Heyer, N.L, (1989), Cellular manufacturing in US industries a survey of users International Journal of Production Research, 27, 1511-1530.
12. Zimmermann,H.J,(1996),Description and optimization of fuzzy systems. International Journal of General Systems, 2,209-215.