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Study on Assumptions, Techniques and Notation to Minimize Total Cost of Inter Cell and Intra Cell Flows

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Abstract— **Our objective is to minimize total cost of inter-cell and intra-cell flows subject to a cell size constraint, i.e., the maximum number of machines allowed in each cell. We consider a center-to center linear distance measure and for simplification, we do not consider any other spatial constraint. However, one may note that such constraints can also be added to the model by some simple modifications to the will-be proposed procedure.**

As the problem of partitioning a manufacturing system into several subsystems, with the objective of minimizing inter-cell flow movement cost is NP-complete (Garey and Johnson (1979)), most researchers have focused on developing heuristics or metaheuristics. In this work, as well, we 100 Saghafian and Akbari Jokar propose an enhanced Simulated Annealing (SA) in which the crossover and mutation operators of Genetic Algorithm (GA) are used as generation mechanism to generate neighborhood solution.

Kirkpatrick, Gelatt and Vecchi (1983) introduced simulated Annealing (SA) and Creny (1985) considered the analogy between the annealing process of solids and the process of solving combinatorial optimization problems. However, it was originally developed as a simulation model for a physical annealing process of condensed matter (Metropolis et al. (1953)). Laarhoven and Aarts (1987) gave a comprehensive discussion of the theory and review of various applications.

Also, they showed that the simulated annealing process converges to the set of global optimal solutions under certain conditions. It starts from an initial solution to the problem, and then generates a new trial solution from the neighborhood at the current solution. If the new solution is better than the current solution it is accepted and used as the new current solution.

Index Terms— **Minimize, machines, annealing, comprehensive, applications.**

I. INTRODUCTION

Bicycle manufacturing sites have been a major vehicle for personal transport for decades. As technology has advanced, the bicycle manufacturing site trend in India has decreased among the middle and highly-earned, but the importance of this trend returns due to fitness and adventure biking priorities. Growing congestion, industrialization, and sustainability are pushing rising cycling demand in India. The state of Punjab was the largest producer of cycles, with almost 10.5 million units produced in 2017. China's bike manufacturers are expected to enter Punjab by incorporating lightweight technologies and stimulating the industry. In addition, it has fueled the growth of India's bicycle manufacturing site industry, with digital shopping growing rapidly and a significant market share anticipated to accelerate and over the forecasted period. The 80 percent of the population who belong to the medium and low-income community and have an increased preference in physique shopping continues to prioritize sales across the period specialty off-line stores. The e-bike movement is gearing up for existing and future enthusiasts to rise [1]. By 2022, e-bikes may produce a 50% stake in the overall bicycle manufacturing site market on a global basis. Brands like Atlas, Hero Cycles, Avon cycles deliver massive consumer presence, low to medium-priced bikes, which accounted for about 60% of 2017's market share. Brands like Firefox and Decathlon's B'Twin penetrate the high price market. In the predicted period of 2017-2030 [2], Goldstein Market Intelligence analysts forecast that the Indian bicycle manufacturing site industry will rise in a CAGR of 8.6%.

Over the past three decades, group technology (GT) has attracted a lot of attention from manufacturers because of its many applications and positive impacts in the batch-type manufacturing system. GT is a manufacturing philosophy that attempts to increase production efficiency by processing part families within machine cells.

The basic idea of GT is to identify and capitalize on the similar attributes of product design and manufacturing processes. Similar parts are grouped into a part family and manufactured by a cluster of dissimilar machines. GT takes full advantage of similarities to develop simplified and rationalized procedures in all stages of design and manufacture. The application of GT results in the mass production effect to multiproduct, small lot-sized production and leads to a lot of advantage s such as reduction of material-handling times and cost, reduction of labours and work works, decrease of in-process inventories, shortening of production lead time, increase of machine utilization, and others (Ham et al. 1985).

II. REVIEW OF LITERATURE

Our objective is to minimize total cost of inter-cell and intra-cell flows subject to a cell size constraint, i.e., the maximum number of machines allowed in each cell. We consider a center-to center linear distance measure and for simplification, we do not consider any other spatial constraint. However, one may note that such

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Also, they showed that the simulated annealing process converges to the set of global optimal solutions under certain conditions. Koulamas et al. (1994) also applied SA to a large number of optimization problems in a verity of application areas. The main procedure of SA can be described as follows. It starts from an initial solution to the problem, and then generates a new trial solution from the neighborhood at the current solution. If the new solution is better than the current solution it is accepted and used as the new current solution. Otherwise, it may be accepted or rejected depending on an acceptance probability, which is determined by the difference between objective function of the two solutions and by a control parameter called temperature, following the convention in thermodynamics. This process then continues from the new current solution. Initially, the temperature is set at high level, as in annealing, so that almost all moves will be accepted. It is then decreased slowly during the procedure until almost no move will be accepted. In other words,

SA procedure can be generally described as following steps.

1. Initialization: set parameters of annealing schedule.

2. Select an iteration mechanism: a simple prescription to generate a transition from current state to another state by a small perturbation.

3. Evaluate the new state and computeΔE = (value of current state - value of new state)

4. If the new state is better, make it current state, otherwise probabilistically accept or reject it (with a determined probability function usually called acceptance probability function).

5. Based on stopping rules either stop or continue iterations at step 2.

III. MATERIAL AND METHOD

This string then will be segmented and each segment represents a machine cell. A Dynamic

Programming approach that uses the idea of a graph of material flow is then used to determine the best cell formation, location sequence and inter-cell flow cost of that cell formation regarding the best layout. Consequently, the number of cells, despite of sequential procedures, is obtained through the optimal policy and is not determined before layout design. After such determination and during our integrative procedure, we will deal with intra-cell layout, i.e., to layout machines in each cell.

This will be done by modeling the problem as a famous Quadratic Assignment Problem (QAP) model and developing an Ant Colony Optimization (ACO) technique to solve it. We use following notations throughout the work.

Integrative Cell Formation and Layout Design… 101 i, j: The index of machines; i, j = 1,…,m;
l,h: The available locations in cells; l,h=1,…C
F: The symmetric flow matrix, F = Fij , where ij ij ji F = f + f and ij f is the amount of material flow from machine i to machine j; k, v: The index of machine cells (or locations), k; v = 1,…,e; where e is the number of machine cells to be determined;

S: The layout assignment vector of all machine cells, S = {s(1),s(2),…,s(e)} where s(v) is the location to which cell v is assigned, s(v) = 1, … , e; π : The permutation of machines in the considered cell for intra-cell layout problem,

π ={π (1),π (2),...,π (C)}whereπ (i) is the machine placed in the ith position ofπ ; s(k),s(v) d : The distance or travel time between cells k and v;
Q: The cell size limit; v q : The number of machines in cell v, which must be equal to or less than Q; k Tabu : The memory of ant k saving the index of machines already assigned by ant k; V k : The memory of ant k saving the moves selected by ant k; il τ : The pheromone level of move v=(i,l).

IV. APPROACH TO MATERIAL FLOW

Here we benefit from the approach first proposed by Lee and Chiang (2001). We know that the material flow F between machines can be described by an undirected graph G(N, A), where N is the set of nodes and each node represents a machine, A is the set of arcs and each arc has the flow ij F Ak v Bk – v Xv Xv k −1 k k +1 connecting the nodes i and j. In this graphical approach, let k A denote the set of those (k-1) cells that have already been assigned to the linear sequence of 1,2,…, and k-1, and k B denote the set of remaining cells that have not been assigned. For any candidate machine cell v in k B to be assigned to the kth site of the linear layout, we partitioned k B into two distinct sets v and k B -v and let v k X = v ∪ A , X B v v k = − (see Figure 1). We define (,) k v v C X X as the increased material flow cost of assigning cell v to the kth location.

Using Graph Theory, it can be shown that the increased inter-cell flow cost of assigning the partitioned cell v to the kth location of linear layout is:
Σ Σ= i X v j X v
k v v ij C (X , X) F .

That is, for the sequence vector { } k k S = A ∪ B , the inter-cell flow cost between k A and kB .

It can be interpreted as all of the material flow that is transshipped from k A at the (k-1)th sequence to k B at the kth sequence. Thus, for the sequence S,
where ( ) k TC A is the total inter-cell flow between the assigned k -1 machine cells in the first k-1
locations of the linear layout. Once the new cell v in k B has been partitioned from k B and
assigned to the kth layout sequence, the first two items in TC(S) become constants. That is,
1, Σ Σ= i Ak j Bk the location vector becomes S {A ,v, B v} k k ′ = − , and its inter-cell flow cost can be estimated by:
Σ Σ Σ Σ Σ Σ =k k k i Ak j Bk v

That is, the increased material flows are those part movements from v to B v k − and from k A to B v k − and the inter-cell flow cost is computed by multiplying the distance dk,k+1 between the two locations. Since the cell locations are assumed approximately equally spaced, 1 1, , 1 = = k − k k k + d d ; and we have:
TC(S) TC(A ,v,B v) k k ′ = −
Σ Σ Σ Σ = k i Ak j Bk v

The increased inter-cell flow cost for the new assignment is equivalent to the minimum cut of the network flow problem in G, where a cut (,) v v X X is the set of arcs with one end in v X and the other end in v X , and the sum of capacities of all the arcs on this cut is the increased inter-cell flow cost. In other words, the cut value is equivalent to the increased inter-cell flow cost of assigning the cell v to the kth location. Starting from the assignment of the first location sequence, the sum of (,) k v v C X X , k = 1,…,e, is the total inter-cell material flow cost in a linear flow layout, and the formulation to solve the joint problem becomes:
Minimize (,) 1 Σ= e
Subject to: | q | Q v 1,...,e. v ≤

CONCLUSION

Moreover, as discussed previously and despite of most available approaches, we will face the intracell layout problem as well. We propose a solution procedure to the related QAP model of this problem as an integrative view of a CMS design. The total intra-cell flow cost of material, which we denote byTC′ , will be added to TC in order to compute the total material handling cost.

REFERENCES

[1]Chan, H.M. and Milner, D. A., 1982, Direct clustering algorithm for group formation in cellular manufacture. Journal of Manufacturing Systems, **1**
[2]Chandrasekharan, M. P. and Rajagopalan, R., 1986, An ideal seed non-hierarchical clustering algorithm for cellular manufacturing. International Journal of Production Research, **24**
[3]Choobineh, F., 1988, A framework for the design of cellular manufacturing systems International Journal of Production Research, **26**
[4]Gupta, T., 1993, Design of manufacturing cells for flexible environment considering alternative routeing. International Journal of Production Research, **31**
[5]Gupta, T. and Seifoddini, H., 1990, Production data based similarity cofficient for machine-component grouping decision in the design of a cellular manufacturing system. International Journal of Production Research, **28**
[6]King, J. R., 1980a, Machine-component group formation in group technology. OMEGA, **8**
[7]King, J. R., 1980b, Machine-component grouping in production of analysis: an approach using a rank order clustering algorithm. International Journal of Production Research, **18**
[8]King, J. R. and Nakornchai, V., 1982, Machine±component group formation in group technology: review and extension. International Journal of Production Research, **20**
[9]Kumar, K. R. and Vannelli, A., 1983, Strategic subcontracting for efficient disaggregated manufacturing. International Journal of Production Research, **21**
[10] Kusiak, A., 1987, The generalized group technology concept. International Journal of Production Research, **25**
[11] Lashkari, R. S. and Gunasingh,K.R., 2010, A Lagrangian relaxation approach to machine allocation in cellular manufacturing systems. Computers and Industrial Engineering, **19**
[12] Logendran, R., 1991, Impact of sequence of operations and layout of cells in cellular manufacturing. International Journal of Production Research, **29**
[13] McAuley, J., 1972, Machine grouping for efficient production. Production Engineer, **51**
[14] Purcheck, G. F. K., 1975, A mathematical classification as a basis for the design of grouptechnology production cells. Production Engineer, **54**
[15] Qiao, L. H., Yang, Z. B. and Wang, H. P., 1994, A computer-aided process planning methodology. Computers in Industry, **255**
[16] Rajagopalan, R. and Batra, J. L., 1975, Design of cellular production systems: a graphtheoretic approach. International Journal of Production Research, **13**
[17] Seifoddini, H. K. and Wolfe, P.M., 1987, Selection of a threshold value based on material handling cost in machine-component grouping. IIE Transactions, **19**
[18] Selim, H.M., Askin, R. G. and Vakharia, A. J., 1998, Cell formation in group technology: review, evaluation and directions for future research. Computers and Industrial Engineering, **34**
[19] Vannelli, A. and Kumar, K. R., 1986, A method forfinding minimal bottle-neck cells for grouping part-machine families. International Journal of Production Research, **24**
[20] Wemmerlov, U. and Hyer, N. L., 1986, Procedures for the part family/machine group identification problem in cellular manufacturing. Journal of Operations Management, **6**
[21] Wemmerlov, U. and Johnson, D. J., 1997, Cellular manufacturing at 46 user plants: implementation experiences and performance improvements. International Journal ofProduction Research, **35**
[22] Won, Y. and Kim, S., 1997, Multiple criteria clustering algorithm for solving the group technology problem with multiple process routings. Computers and Industrial Engineering, **32**

[23] Yasuda,K. and Yin, Y., 2001, A dissimilarity measure for solving the cell formation problem in cellular manufacturing. Computers and Industrial Engineering, **39**

[24] Zhao, C. W. and Wu, Z. M., 2000, A genetic algorithm for manufacturing cell formation with multiple routes and multiple objectives. International Journal of Production Research, **38**.

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