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EVALUATION ON THE SYSTEM PERFORMANCE BETWEEN CELLUAR AND PROCESS MANUFACTURING LAYOUTS

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Abstract

Cellular Manufacturing with Group Technology has received a great deal of attention during past two decades. Though the literatures declare that Cellular Manufacturing can gain the economic advantages in small batch-type production and retain the flexibility, these studies lack of systematic evaluation.

This research tries to develop a systematic approach to identify the efficiency of clustering algorithms which decides the cells and groups in the first stage of planning for cellular manufacturing. Various clustering methods are evaluated. The cellular layout versus process layout was tested using simulation models.

Keywords: Simulation, Cellular layout, Process layout, and Group technology.

Introduction

The past three decades have provided diverse researches directed toward the problems of traditional batch manufacturing and their remedy through the employment of newly developed automated manufacturing systems. Early researchers recognized the importance of providing the automatic routing for jobs through a processing facility and the need to reduce equipment setup delays. In the 1960's and 70's, several independent groups observed that these needs could be met through the aid of the computer and process control techniques. This, in turn, has led to the development of the concept most often referred to today as the concepts of Group Technology (GT) and the Flexible Manufacturing System. (FMS)

In recent years, the industrial job shops have faced an increase in complexity and a decline

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in productivity due to part mix, volume of parts, plant size, machine production rates, and part complexity. One result of the increased complexity and reduced productivity is the development of Group Technology and Cellular manufacturing which seeks to eliminate or minimize complexity and to improve or maximize productivity.

Simulations Models and Results

The objective of the simulations was to investigate the performance for cellular layout and process layout through three ranges of part demand distributions. The simulation models are run on the IBM CMS/VMS mainframe at University of Texas at Arlington. Each model was run 1750 simulated days (seven years) for a start-up period, during which time data was not collected. Following the warm-up period, the data were collected for every 500 simulated days (two simulated years) and total 20 years' data were collected.

2.1 Model Building

Table 2.1 gives the illustration of the combinations used in the study. There are two factors: layouts and parts demand distributions. Two alternative layouts, cellular layout and process layout, and three levels of part demand distributions were listed in Table 2.1.

Table 2.1 Model Building

	WMO*	WEO*	WLO*
Cellular layout			
Process layout			

*The WMO distribution is biased towards those parts require the most operations. The WEO distribution uses an equal demand for all the parts. The WLO distribution is biased towards those parts require the least operations.

2.2 Program

The simulation models are implemented by using SLAM II software and FORTRAN user written subroutine. There are six programs total to simulate the six experiments. It includes five discrete events in cellular layout models and six discrete events in process layout models. The events are illustrated as SLAM II flowcharts.

2.3 Variables and Functions

The definitions of variables used in the simulation models are describes in the Table 2.2. Table 2.3 expresses the SLAM II functions used in the programs. Cumulative parts demand distributions is listed in the Table 2.4. to Table 2.6.

Table 2.2 Definitions of Variables

Variable		Definition
In Cellular Layout	In Process Layout	
ATRIB(1)	ATRIB(1)	Part number
ATRIB(2)	ATRIB(2)	Sequence number
ATRIB(3)	ATRIB(3)	"From" machine
ATRIB(4)	ATRIB(4)	"To" dedicated machine
ATRIB(5)		"To" type of machine
ATRIB(6)	ATRIB(5)	Type of handling equipment
ATRIB(7)	ATRIB(6)	Specific material handler
ATRIB(8)	ATRIB(7)	Time of creation
ATRIB(9)	ATRIB(8)	Operation completed in the sequence
ATRIB(10)	ATRIB(9)	Total operations done
ATRIB(11)	ATRIB(10)	Run time
ATRIB(12)	ATRIB(11)	Setup time
TNOW		Current time
XX(I)		The number of busy machine
	NUM(I)	The total number machine available
ARR		Interarrival time for the whole batch
BATCH(I)		Batch size
CONVYR(I)		Conveyor status
FORK(I)		Fork status
MANUAL(I)		Workers status
PART(I)		Last part
SEQ(I)		Last sequence
NNQ		Number in queue
	AVAIL(I)	First machine ID

Table 2.3 SLAM II Functions

Function	Description
SCHDL(KEVNT,DTIME,A)	Schedule events
RMOVE(NRANK,IFILE,A)	Remove an entry from file
FILEM(IFILE , A)	Files an entry into file IFILE.
UNFRM(ULO, UHI, IS)	A uniform distribution
EXPON(XMN, IS)	An exponential distribution
COLCT(XVAL,ICLCT)	Obtain statistics

2.4 Data Analysis

This section describes the results obtained from the six simulation models. The following output parameters were selected and simulation results were collected for each parameter.

1.Average Setup Time: it is expressed as days per setup. The assumed values were 0 or .25 days in cellular layout and 0.0, .25, or 1.0 in process layout and it is determined by the sequence of parts arriving at a machine related to the previous part processed.

2.Average Distance Traveled: The distance between machines and the distance between machines and raw materials inventory are calculated per batch.

3.Average Throughput Time: It is calculated for each batch spent in the system, from its release from raw material inventory until its final process, and is averaged over batch during a simulated year. The unit is days per batch.

4.Average Machine Utilization: The average percent per year is expressed as the time that each machine is running or being set up during a simulated year.

5.Average Queue Length: It is calculated over all machine queues for a year. The terms of parts are expressed in order to facilitate comparison between models with different batch sizes.

6.Average Waiting Time: The time that each batch has to wait in each machine queue during a simulated year is calculated as average waiting time. It does not include the material handling queues.

7.Longest Queue Length: It is a measure of the variability between queues. Queues of material handling were not considered. The longest queue for each year was observed.

8.Longest Waiting Time: It is a measure of the variability between waiting times within machine queues. Queues of material handling are not considered. It is determined for each simulated year.

2.5. Simulation Results

The investigation of cellular layout versus process layout was simulated and the data representations are shown as Table 2.4 to 2.7. Figure 2.1 to 2.3 illustrates the eight variables recorded for each of three parts demand distributions. As expected, the cellular layout is the best performer with respect to setup time and distance moved. However, the process layout outperforms the cellular layout on machine utilization. The following example explains why longer queue might be created in the cellular layout.

Let us consider an example in which a job shop has a machine components that consists of two lathes and a variety of other types of equipment. Consider two parts orders arriving when the system empty, and both require two hours of processing time on a lathe. In the process layout the lathes department can accommodate both parts immediately. Assume the cellular layout is organized with two cells and one lathe located in each cell, when both parts orders are routed to the same cell, one order must wait in line until the other has finished. Thus creating a small bottleneck. Then the utilization for the lathes would be 100% in process layout and only 50% in the cellular layout during the first 2 hours.

Comparing the results from Figure 2.1 to Figure 2.3, the different demand distributions do not have significant effect on our shop model. In the WMO model, the exceptions lead to higher throughput and longer queue. The reason was explained in above example. To sum up, the exception is the key point to influence the performance of the cellular layout. The summary of planned comparisons is listed in the Table 2.7.

Table 2.4 Summary Report by WMO

	Variable	Cellular layout	Process layout
1	Ave. setup time (Days)	.25	.7918
2	Ave. distance/move (Feet)	29.08	30.74
3	Ave. machine Utilization (%)	58.24	72.37
4	Ave. queue length (Parts)	2.43	16.31
5	Ave. waiting time (Days)	7.65	16.06
6	Longest ave. queue (Parts)	50.09	103.44
7	Longest ave. wait (Days)	117.03	56.34
8	Ave. throughput time (Days)	209.12	120.32

Table 2.5 Summary Report by WEO

	Variable	Cellular layout	Process layout
1	Ave. setup time (Days)	.25	.7932
2	Ave. distance/move (Feet)	29.24	30.57
3	Ave. machine Utilization (%)	52.78	69.8
4	Ave. queue length (Parts)	.843	12.26
5	Ave. waiting time (Days)	8.45	14.88
6	Longest ave. queue (Parts)	7.91	60.16
7	Longest ave. wait (Days)	39.54	64.27
8	Ave. throughput time (Days)	94.22	110.68

Table 2.6 Summary Report by WLO

	Variable	Cellular layout	Process layout
1	Ave. setup time (Days)	.25	.791
2	Ave. distance/move (Feet)	30.51	30.73
3	Ave. machine Utilization (%)	52.18	71.98
4	Ave. queue length (Parts)	.69	10.82
5	Ave. waiting time (Days)	7.67	16.22
6	Longest ave. queue (Parts)	4.22	66.71
7	Longest ave. wait (Days)	21.99	59.14
8	Ave. throughput time (Days)	81.66	107.59

Table 2.7 Summary of Simulations

		WMO	WEO	WLO
1	SETUP TIME	CELL < PROCESS	CELL < PROCESS	CELL < PROCESS
2	DISTANCE	CELL < PROCESS	CELL < PROCESS	CELL < PROCESS
3	UTILIZATION	CELL < PROCESS	CELL < PROCESS	CELL < PROCESS
4	QUEUE L.	CELL < PROCESS	CELL < PROCESS	CELL < PROCESS
5	WAITING TIME	CELL < PROCESS	CELL < PROCESS	CELL < PROCESS
6	L. QUEUE	CELL < PROCESS	CELL < PROCESS	CELL < PROCESS
7	L. WAIT	CELL > PROCESS	CELL < PROCESS	CELL < PROCESS
8	THROUGHPUT	CELL > PROCESS	CELL < PROCESS	CELL < PROCESS

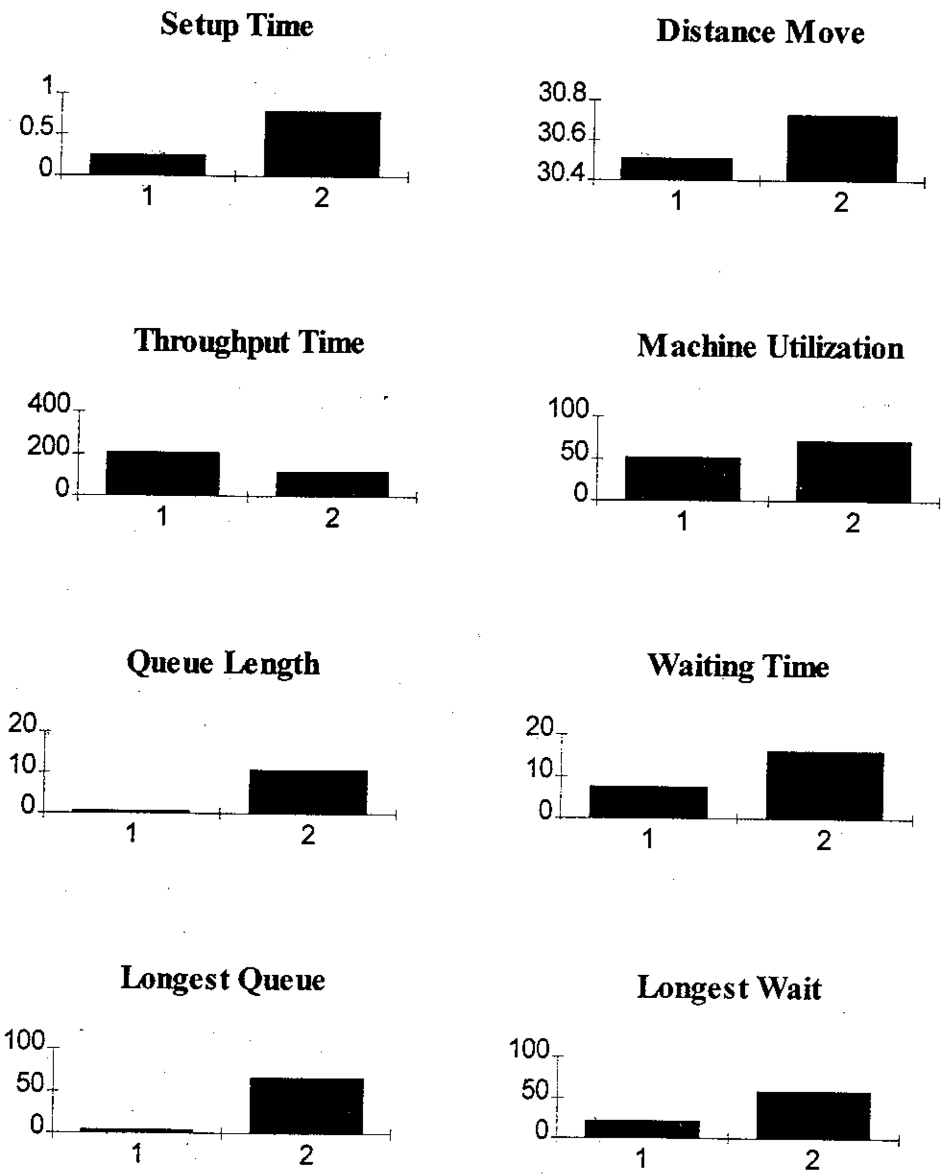

Figure 2. 1 Comparisons by WMO (1= Cellular layout, 2= Process layout.)

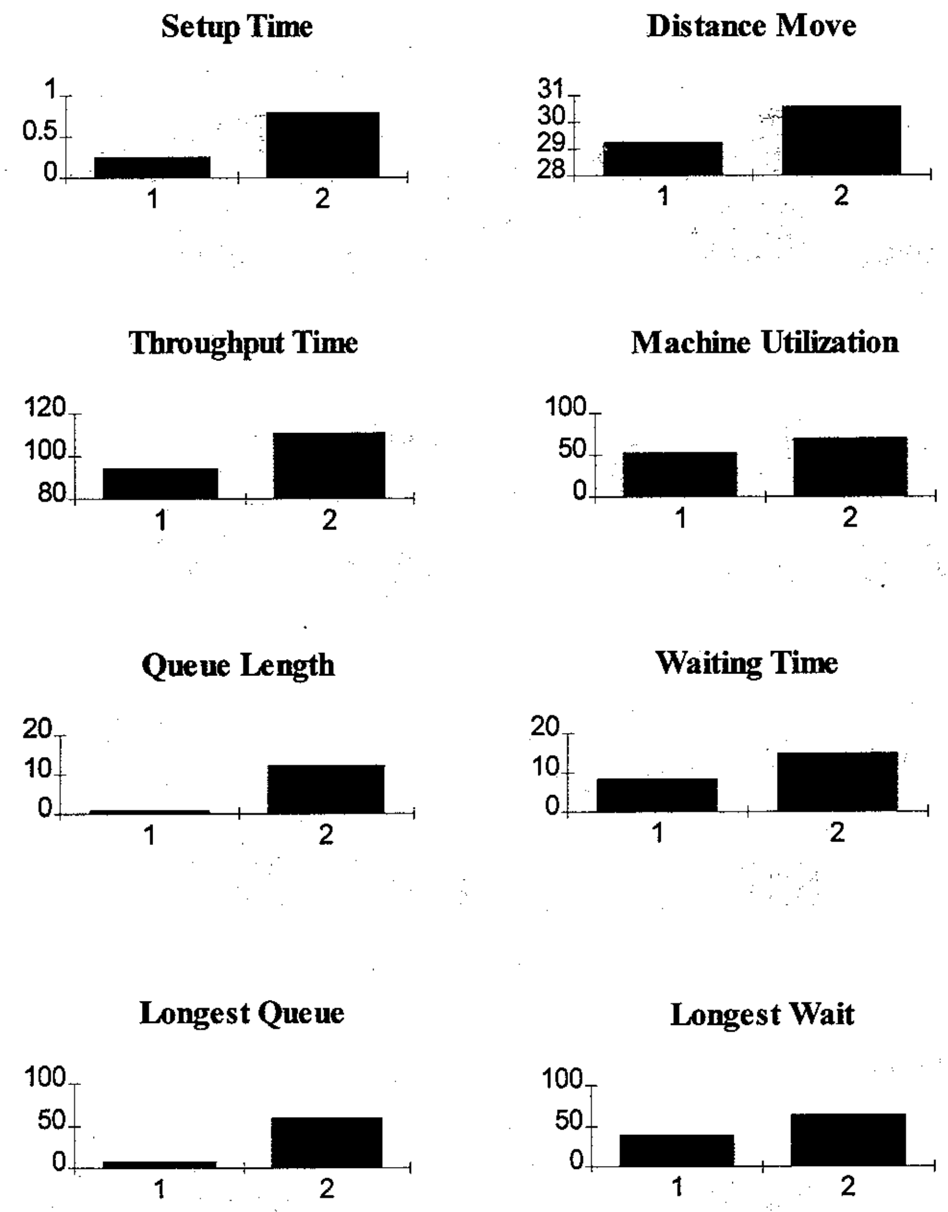

Figure 2.2 Comparisons by WEO (1= Cellular layout, 2= Process layout.)

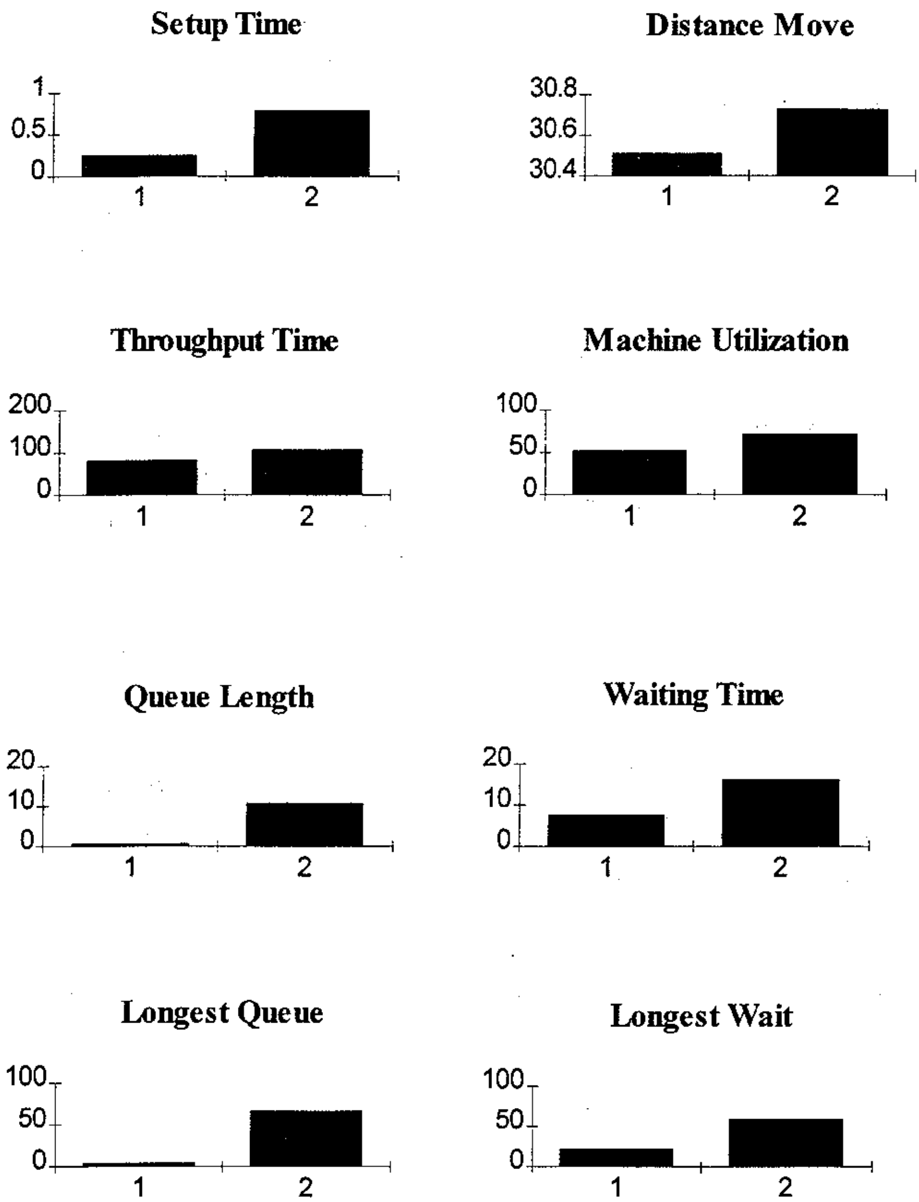

Figure 2.3 Comparisons by WLO (1= Cellular layout, 2= Process layout.)

Conclusions and Recommendations

Briefly, the research questions addressed in this research are:

(1)Bring together information on a number of the clustering algorithms, review their advantages, summit some of them to performance evaluation.

(2)Compare cellular layouts with process layouts and evaluate several performance statistics token under a variety of conditions.

It seems that there are two fundamental methods for evaluating alternative layout designs, these have being the application of some measures of performances (as in the clustering algorithms) and in measuring the performance in a realistic environment. The later of these two would be impossible to accomplish in the real world but the measures of performance are rigorous and are a valid indicator of effectiveness. Likewise, we could not realistically perform a real world experiment to evaluate the cellular manufacturing by rearranging equipment in someone's factory but the use of computer simulation does provide a valuable alternative.

3.1 Limitations of Findings

Although care was taken to reduce conflicting or biased results, there are potential sources of error remaining in the research. The most substantial threat is to the external validity of the results since the simulation model of a real system necessarily involves some simplifications. A limited set of conditions and assumptions was used to construct the job shop environment. The restriction are as follows:

(1)Different values for setup and moving time, demand patterns, and scheduling rules might be tested to increase the validity of the research. Fixed setup time and one arrival rate of orders were used.

(2)Experimental conditions that remain in real world need to be collected. However, time and cost do not permit. Random generated data might not match exactly the real world.

(3)Even the scheduling and sequencing literature supported for limiting the size of the machine component, more data sets could be considered to run the simulation to achieved more reliable results.

(4)One resource constraint, the assumption of adequate number of workers, was tested in the model. It is possible that a dual resource (labor and equipment) will give different results.

(5)Machine breakdown and workers absenteeism would lead to different performance values.

Cellular system has no internal flexibility to re-route parts. Above two factors will occur in real system.

(6)Only one repetitive lots rule was used in the machine queues. Other priority disciplines would change the values reported in the study.

(7)Job satisfaction and motivation were not considered in the research. The assumption of uniform performance was assumed.

(8)The cost associated with reconfiguration equipment was not measured. The availability of under employed, temporarily idle workers, and outside contractors to complete the same tasks would be very difficult to evaluate and simulate.

(9)Human response and management policy in a effort to improve productivity would cause change the performance of cellular manufacturing. Again, it would be difficult to get the data to model.

3.2 Recommendations for Future Research

There are a number of possible areas for additional work to be built upon the results in this study. The details are listed as follows:

1.Improve the flexibility of cellular manufacturing. The inter cell routing of parts reduce the waiting time and machine utilization. Remember that such action will probably increase setup time. Developing a methodology to optimize the flexibility will clarify the performance of cellular manufacturing.

2.Including an expert system with the clustering algorithms may help the simulation of the real world.

3.Since clustering analysis in machine/part matrix is a dynamic problem as traveling sales man problem, use neural network to identify the cluster as same pattern could be possible if we could train enough row/column in system.

4.Including the queue priority disciplines (FIFO, FILO, shortest processing time, etc.) into simulation models to confirm the performance of cellular manufacturing.

5.Additional survey and plant visits are needed to verify the operating environment and management practices that are currently being used in cellular manufacturing.

6.More sensitivity studies are necessary to investigate factors like setup time variability in future. Labor constraints, machine breakdowns, scheduled maintenance, machine capacities, and material handling requirements within department could also incorporated into the simulation models to assess their relative influence on the cell and flow layout.

Summary

Cellular manufacturing does appear to provide a "prescription for much of the world of work" as Schonberger (1985) suggests. The demand for flexibility in operations will continue to pressure managers and decision-makers for innovative approaches that reduce unit costs for small batches of products. Even the cellular manufacturing appear better performance in our study, to implement cellular manufacturing in real world still need deep analysis in firms. In reviewing the cellular formation problems, following points are needed to aware:

1. The multitude of clustering algorithms, clustering criteria, and measures of performance make it difficult to evaluate and select an appropriate of better clustering methods.
2. Different clustering criteria may produce different grouping results even if the same algorithm and data are used.
3. Most clustering algorithms do not take processing time and production volume into consideration. Some new measure factors need to be considered.
4. The quality of clustering depends highly on the quality of data.
5. The determination of an optimal number of manufacturing cells is a controversial issue.

To sum up, cellular manufacturing might take the benefits if the cellular systems are carefully designed. To remove bottleneck problems will affect the performance of cellular manufacturing. Through it is the road to FMS and it would be convenient to consider the sharing data base and processing sequences during the clustering and designing stage, still the problem of integration remains a tough issue.

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模擬群集與流程製造佈置的績效評估

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摘要

應用群組化技術之群集製造佈置，在過去數十年中引起極大的注意，已有的研究文獻皆宣稱群集方法在小批次量的生產中具有經濟效益與製造彈性，然而研究中廣泛缺少系統性的評估。

本研究企圖以系統化的模擬來確認各群集演繹法在生產流程上的效率；不同的群集方法在群集佈置與流程佈置的表現，皆以模擬程式測試後予以詳盡探討。

關鍵字：模擬、群集佈置、流程佈置、群組化技術

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