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A SIMULATION ANALYSIS OF THE EFFECTS OF SYSTEM PARAMETERS AND OPERATING STRATEGIES ON THE PERFORMANCE OF CELLULAR MANUFACTURING SYSTEMS

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دراسه تحليليه لتأثيرات عناصر واستراتيجيات التشغيل على أداء نظم الانتاج الخلويه

خلاصة:

يهدف هدا البحث الى التحقق من تاثيرات ظروف و عناصر التشغيل على اداء ورشه خلويه. وقد تم اعتبار معدل وقت الأنسياب للمشغولات والانحراف المعياري لوقت الأنسياب و المخزون تحت التشغيل والانحراف المعياري للمخزون تحت التشغيل كمعيار لاداء هده الورشه. كما واستخدمت نمادج المحاكاة با ستخدام لغة المحاكاة (SLAMII) للحصول على البيانات لهده الدراسه. خمسة عناصر تشغيليه نم اعتبارها في الدراسه هي: حركة المشغولات بين خلايا الورشه وحجم رزمة التشغيل والتغير في وقت التشغيل ومعيار تجهيز الماكنات والتغير في وقت تعطل الماكنات. بينت نتائج هدا البحث بان هناك توافق ما بين معايير الأداء المستخدمه بالاضافة الى تأثرها بشكل كبير في ظروف تشغيل الورشه. كما وأن التأثيرات الداخليه ما بين عناصرظروف التشغيل لها فاعليه عاليه في التأثير على أداء ألورشه.

Abstract

This paper aims to investigate the effects of system parameters on cellular shop performance. Mean flow time, standard deviation of flow time, work-in-process, and standard deviation of work-in-process are the shop performance measures considered. Simulation modeling using SLAMII is used as a vehicle to generate experimental data. Five system parameters (factors) are considered in this study: job movement among shop cells, job batch sizing, job processing time variability, machine setup index, and variability in machine time between breakdowns. It was found that shop performance measures are correlated, and are highly affected by the experimental conditions considered. System parameters interactions were also found to be significant in terms of their impact on shop performance.

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1- Introduction

The concepts of group technology (GT) and cellular manufacturing (CM) have been recognized among the most effective strategies in the field of production and have become of wide popularity in both academic industrial application [27]. GT has been introduced in the manufacturing philosophy during the 1940s [3], and is known today as cellular manufacturing. It is best suited for production systems where many different parts with low demand volumes are produced in small batch sizes [8]. Cellular manufacturing involves the grouping of parts into part families and machines into machine cells so that a family of parts can be processed within a cell of machines. There are several reasons for the establishment of cellular production systems using group technology techniques. Among them are the reduction in machine setup times, reduction in throughput time, reduction in material handling requirements, reduction in work in process inventory, improvement of quality, improved worker moral due to grouping and reduced expediting [12], [32]. During the last two decades, CM has been considered as an attractive alternative to manufacturing job shops [4], [19].

Despite benefits and operational advantages gained by the application of the GT concept, it is real potential has not been fully explored. A number of factors, including machine breakdown, under utilization of resources and eventually unbalanced workload distribution in a cellular manufacturing system, create some problems when using the GT concept. These problems mainly stem from the avoidance of interaction between cells, tendency to setting-up permanent idealistic cells, changes in product mix, changes in product design and changes in product demand. Such problems can eventually lead to an overall deterioration of the production efficiency. It has been shown in the literature that a possible significant improvement in the overall system performance can be achieved by exercising controlled interaction between cells [36].

A large number of research papers and reports have been published in the field of cellular manufacturing. Heuristics and non-heuristic methods have been developed by [1], [2], [7], [17], [18], [22], [24], [25], [30], [37], [41]. The evaluation of cell formation solutions has remained somewhat qualitative [5], [38]. Some of the commonly used evaluation measures for cell formation are the number of inter and inner-cell moves, the number and cost of duplicate equipment, the number of parts removed from the system, and machine utilization [1], [2], [6], [21], [25], [30], [31], [33], [37]. In particular, cell formation techniques have usually been compared in relation to the number of exceptional elements generated in the solutions [2], [5], [37]. It has been shown in the literature that the CF problem is difficult to solve and that a relaxed version of it is NP-complete [27].

Most of the suggested algorithms in the literature are either not amenable to large size problems or are computationally prohibitive in real industrial applications. In the cell formation (CF) problem, there are many factors that should be taken into consideration such as machining time, utilization, workload, multiple routing, capacities, operation sequence and cells configuration. It is impossible to consider all of these factors in one algorithm. Therefore, various algorithms using different techniques have been presented based on the different factors considered. Additional reviews may be found, for example, in [2], [9], [22], [23], [33], and [35].

The goal of this research is to investigate the effects of system parameters and operating strategies on the performance of production systems organized as cellular manufacturing systems. System parameters considered in this study, as experimental factors, are: order processing time variability, order transfer batch size, inter-cell movement between manufacturing cells, machine time between breakdowns variability, and setup ratio. The system performance criteria used are mean flow time, variance of flow time, and average work in process inventory. A computer simulation methodology will be used to model hypothetical cellular manufacturing systems to generate data. Simulation as a tool for systems analysis has proven records in the literature [14].

2. Experimental design

The experimental design is concerned with: (1) selecting a set of input variables (i.e. factors) for the simulation model; (2) setting the levels of the selected factors of the model; and (3) deciding on the length of runs and the number of replications for each run, under which the model will be run.

A full factorial experiment was designed to investigate the effects of system parameters on the shop performance. The experiment included five factors: inter-cell movement, order transfer batch size, variability of processing time, setup index, and variability of time between machine breakdowns. Four shop performance measures are considered in this study: (1) order mean flow time, (2) standard deviation of order flow time, (3) work in process inventory, and (4) standard deviation of work in process inventory.

Two levels of inter-cell movement are considered: 0.0% and 40%. The first level (0.0%) means that there is no inter-cell movement (i.e. all parts are processed inside their assigned cells, while the other level means that 40% of the part operations are processed outside their assigned cells (i.e. 40% of the parts are allowed to move to cells other than their dedicated ones). To control the level of inter-cell moves in the simulation runs, the processing routings of some parts are changed in such a way that more parts require processing in more than one cell. However the first two operations on a par are processed in its assigned cell and a maximum of two operations on a part can be processed outside its assigned cell. A survey of cellular manufacturing users found that only 10% of the surveyed shops processed parts completely within cells (i.e. no inter-cell movement) [38].

Two levels of the batch size (transfer quantity) factor are included in the experiment: 5, and 30 units. The larger the batch size for a part the smaller is the number of batches per part order. Although it takes longer to process a large batch, but large batch sizes lead to reduced total setup time in the shop for a given amount of work. A constant order size of sixty units is assigned to all part types as they enter the shop.

A major setup time is defined as the setup time incurred when a part is processed outside its assigned cell. A minor setup time is the setup time required when a part is processed in its assigned cell while major setup time is the setup time required when a batch is processed on machines outside its assigned cell time. The ratio between minor setup time and major setup time is usually called the setup ratio and commonly used in the literature as a measure of the level of the setup time reduction resulting from the dedication of cells to parts in cellular manufacturing shops. Two levels of setup ratio are considered in the experiment: 2/3 and 1/6. The setup ratio is represented in the experiment by a setup index which is a real multiplier equal to the reciprocal of the setup ratio. Therefore two setup multipliers of 1.5 and 6 corresponding to the mentioned setup ratios are used in the simulation model. These levels are selected within the practical setup ratio range found in practice [39]. The major setup time can be determined from a known minor setup time using a setup ratio of, say, (2/3) as the product of a setup index of 1.5 and the known minor setup time. Minor setup time is deterministic with a value of eighteen minutes (i.e. three times unit mean processing time). The range of resulting ratios of minor setup time to mean processing time used in this study is consistent with values used in previous research involving shop simulation, for example in [10].

Processing time variability is specified at two levels of coefficient of variation: 0.0, and 1.0. The processing time for each part is probabilistic and drawn from an exponential distribution with mean of 0.1 hr. The batch processing time is the product of unit processing time and batch size. The exponential probability distribution has been used in the literature to model parts processing time [13], [40].

Machine breakdowns occur with a time between breakdowns (TBBD) generated using an exponential probability distribution with a mean of 15 hrs and two levels of variability in terms of its coefficient of variation: 0.0, and 1.0. Machine repair time is drawn from a uniform distribution with a mean of 1 hr and a coefficient of variation of 0.2. These probability distributions were used in previous research [40]. The breakdown of each machine is modelled using a breakdown entity which preempts the machine and holds it while a repair operation is performed. The breakdown entity is processed through a disjoint network segment in the model. Table 1 summarizes these experimental factors and their corresponding levels. The total number of experimental factor combinations is equal to 2X2X2X2X2=32 combinations (different operating conditions).

Experimental Factor	Factor Levels	
	Low	High
1- Inter-cell movement (CM)-F1	0.0%	40%
2- Batch size (BS)-F2	5	30
3- Processing time coefficient of variation (PTCV)-F3	0.0	1.0
4- Setup index (SI)-F4	1.5	6.0
5- Time between breakdowns coefficient of variation (TBBDCV)-F5	0.0	1.0

Table 1: Experimental factors and their levels.

Another important consideration in experimental design is to decide on the nature of simulation runs as well as the number of replications. In this study the cellular manufacturing system is simulated for a period of 1.5 year (30000 hrs), equivalent to the completion of 1500 orders with a warm-up period of (1000 hrs), equivalent to the completion of 500 orders. It was determined in pilot runs that the system reaches its steady state after 1000 hrs. Therefore, statistics on performance measures were collected over 3000 hrs after the warm-up period. Previous research [26] suggested that at least three replications of the simulation should be made to assess the variability of the output analysis, but in this study, four replications are considered and a total of 32X4=128 runs for all experimental factor combinations were made.

3. Cellular shop model

Computer simulation was used to model a cellular shop consisting of four machine cells, each cell containing four non-identical machines, for a total of 16 machines in the shop as shown in Figure 1. The shop model is intended to represent a typical cellular manufacturing shop. The cell size of 4 machines is consistent with the average cell size of 4.7 machines used by the CM users [38]. Each cell is dedicated to one part family, and each part family has five distinct part routings corresponding to five part types. Thus a

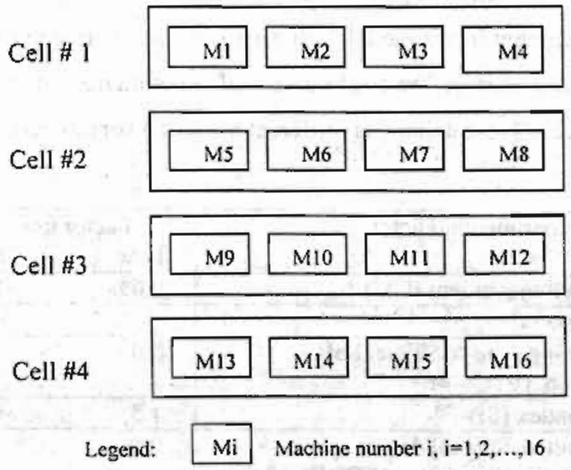


Figure 1: Cellular shop model.

total of 20 part types are being processed in the cellular shop. A first-come first-served (FCFS) priority rule is used to select parts from machine queues. The probability of assigning each part to a part family and having any of the possible routing is equal. Table 2 presents the 20 machine part routings considered in the initial scenario with no inter-cell movement is allowed. A part type is represented by two digits, the first digits indicates the part family and the second digit indicates the part number within that part family.

Part family	Part type	Machine sequence (routing)
1	11	M1-M3-M2-M4
	12	M4-M1-M2-M3
	13	M4-M3-M1-M2
	14	M2-M3-M4-M1
	15	M1-M2M-4M-3
2	21	M5-M6-M7-M8
	22	M7-M8-M5-M6
	23	M6-M7-M8-M5
	24	M8-M6-M5-M7
	25	M8-M7-M5-M6

Part family	Part type	Machine sequence (routing)
3	31	M12-M11-M9-M10
	32	M10-M9-M12-M11
	33	M11-M9-M12-M10
	34	M10-M11-M9-M12
	35	M11-M12-M10-M9
4	41	M13-M15-M16-M14
	42	M15-M13-M14-M16
	43	M14-M16-M15-M13
	44	M13-M15-M14-M16
	45	M15-M14-M13-M15

Table 2: Part routings for inter-cell movement factor 0.0.

Each cell is assumed to be machine constrained only, and cycling is not allowed. It is also assumed that each cell has already been designed and setup, and processing information is available. No setup time is required when batches of identical parts are successively processed by a machine. These assumptions are consistent with the literature [28]. Finally, each part has four different operations to be processed on machines and movement of batches within a cell in not dependent upon a limited resource and therefore within cell moves are not accounted for in the simulation. However, the handling time required to move a batch between cells is set to 0.5 hr which represents a range from 8% to 100% of the mean batch processing time.

Part orders of size 60 units arrive to the shop according to a Poisson process . Upon arrival, each part order is assigned through a discrete event subroutine a part family, a part number, a part processing time, a transfer batch size, and a minor setup time. Then batches are routed to the first machine on their routings. Arrival rate was adjusted for each scenario (factor combination) considered so that an average shop utilization across all machines is maintained in the range of 70% to 80%. This is consistent with typical values found in practice. It is reported in a survey [39} that the ranges of the average lowest and the average highest utilization found in firms involved in cellular manufacturing are 32% to 89%.

The manufacturing simulation model of the cellular manufacturing system described above is programmed in SLAM II simulation language [29]. The simulation model is composed of four modules: (1) the SLAMII network, (2) the Event module, (3) the User Inserts Subroutine module, and (4) the OUTPUT module. The SLAMII network model deals with the details and layout of the manufacturing shop, the EVENT module links between the network model and the user inserts subroutines, written in Fortran, that specifies shop parameters (factors), operating strategies and the dynamic nature of the model. The OUTPUT module is used to generate and report data sets of the simulation runs. Samples of SLAM II networks and user's insert subroutines for this simulation model are provided in the Appendix.

4. Results and discussions

Mean flow time (MFT), standard deviation of flow time (SDFT), work-in-process (WIP), and standard deviation of work-in-process (SDWIP) were used as the cellular shop performance measures in the experiment. MFT is the mean flow time of all orders finished within the simulation time. WIP is the time-weighted average number of unfinished units in the shop during the simulation time. Correlation tests performed on the collected statistics of these variables showed that they are highly correlated as presented in Table 3. Therefore, results and discussions are reported only for MFT in this paper.

Analysis of variance (ANOVA) was used to statistically analyze the collected data. The ANOVA test showed that all main effects (factors) and most of the first and second order interactions are highly significant at the 0.05 significance level as shown in Table 4. Because of the many significant interactions among the experimental factors considered, no specific conclusions can be drawn on the effects of individual factors on the MFT by using ANOVA test. Therefore, individual results on each combination of the factors

	WIP	FFT	SDFT	SDWIP
WIP	1.000	0.996**	0.958**	0.661**
FT	0.996**	1.000	0.972**	0.647**
SDFT	0.958**	0.972**	1.000	0.659**
SDWIP	0.661**	0.647**	0.659**	1.000

Legend:

** Correlation is significant at the 0.01 level.
WIP: work in progress; FT = Mean flow time.
SDWIP: Standard deviation of WIP; SDFT: Standard deviation of FT.

Table 3 : Correlation coefficients of performance measures considered in the experiment .

(operating condition) considered in the experiment must be compared separately. Matched pairs t-test was used to test for significance in MFT observed under each of the operating conditions considered The matched pairs t-test was used in previous research as in [15].

Source of variation	F statistics	Prob.> F	Source of variation	F statistics	Prob.> F
Corrected Model	30.952	.000	CM * BS * PTCV	18.596	.000
Intercept	6665.728	.000	CM * SI	22.751	.000
CM	110.418	.000	BS * SI	18.894	.000
BS	106.783	.000	CM * BS * SI	13.814	.000
PTCV	415.978	.000	PTCV * SI	32.099	.000
SI	32.986	.000	CM * PTCV * SI	22.016	.000
TBBDCV	30.614	.000	BS * PTCV * SI	21.843	.000
CM * BS	31.788	.000	CM * BS * PTCV * SI	16.352	.000
CM * PTCV	31.940	.000	PTCV * TBBDCV	6.909	.010
BS * PTCV	22.360	.000			

Table 4: Summary of ANOVA results.

Figure 2:(a)-(e) presents the results obtained on the effect of each of the factors considered in the experiment on MFT performance measure. It is evident from the graphs that operating the cellular shop at a high level of any of the inter-cell movement (CM), processing time coefficient of variation (PTCV), setup index (SI), and time between breakdowns coefficient of variation (TBBD) results in a negative effect on MFT. While

operating at a high level of the batch size factor (BS) leads to a positive impact on MFT. Figure 3:(a)–(d) presents the relationships between MFT and the CM factor both high and low levels of each of the factors BS, PTCV, SI, and TBBDCV. It can be seen from these

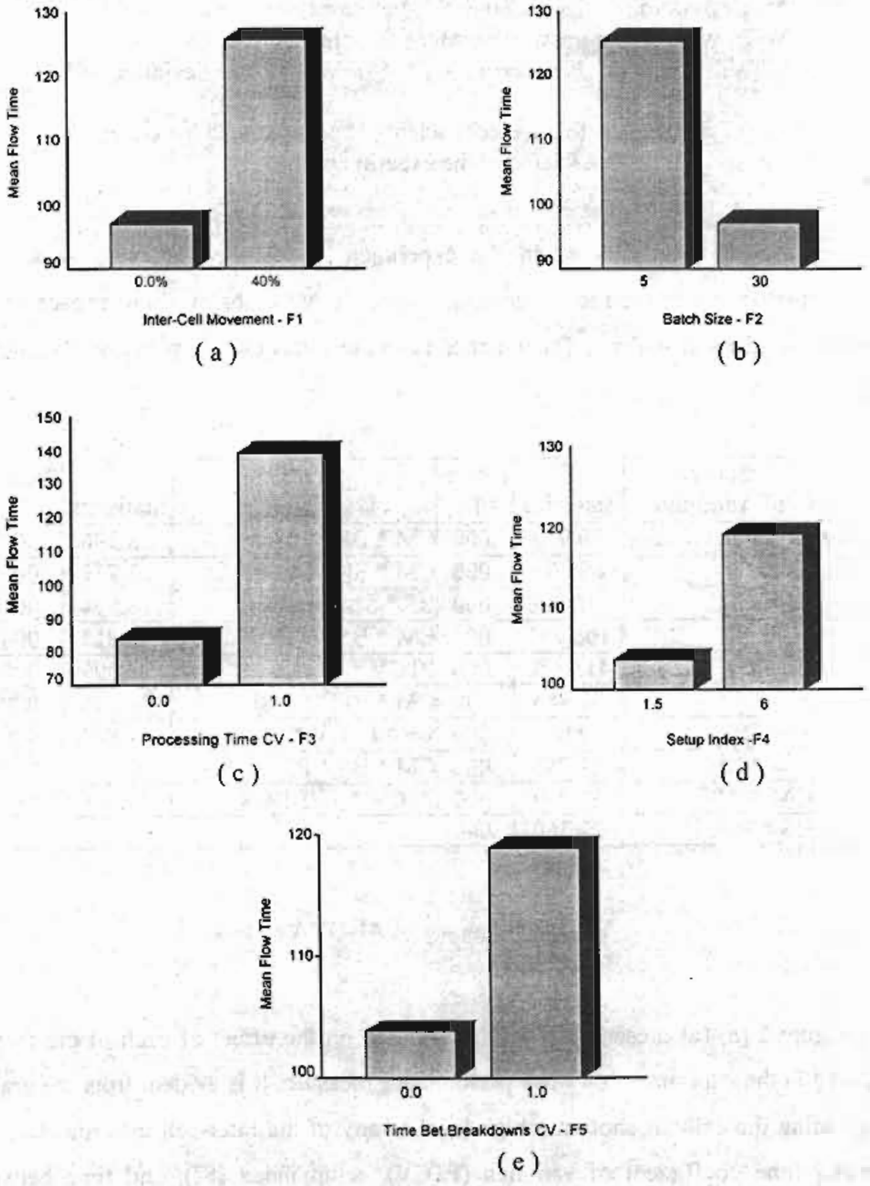
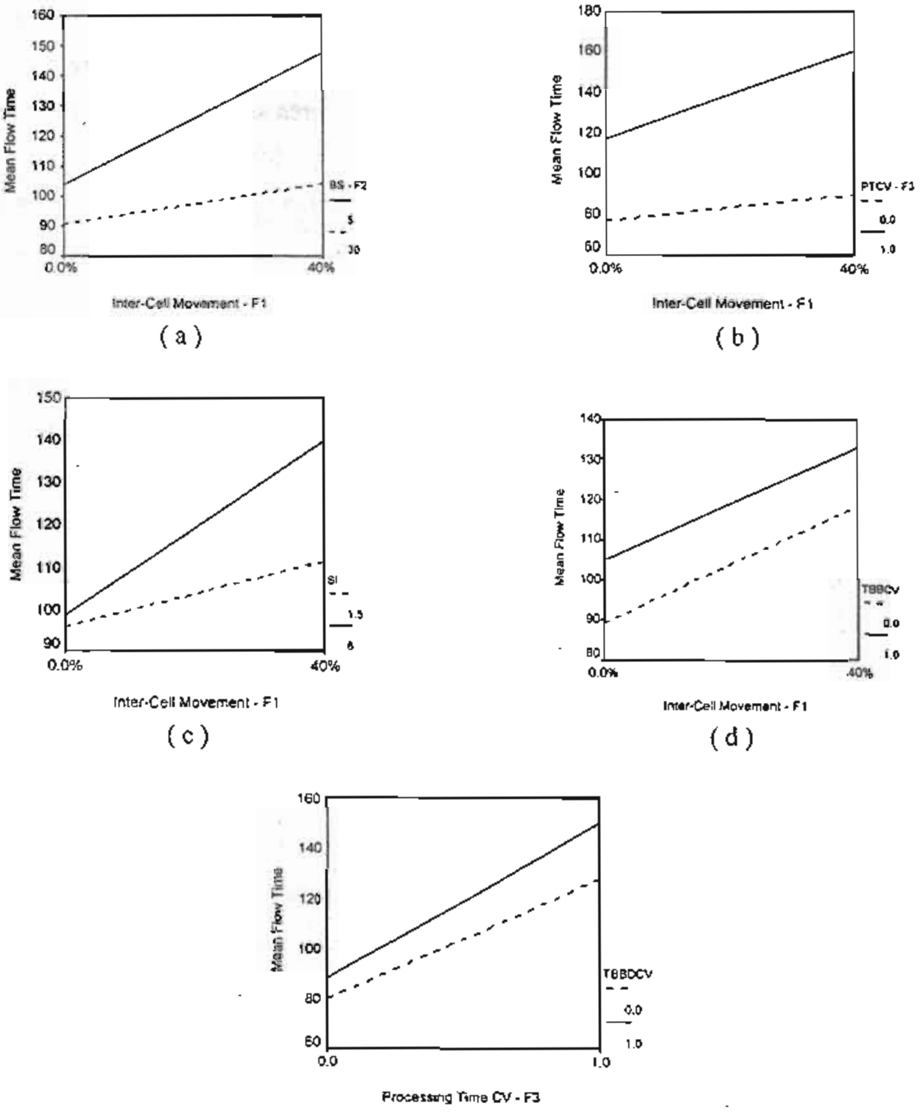


Figure 2: Mean flow time as a function of experimental factors.

relationships that MFT is negatively affected by operating the cellular shop at high levels of these factors indicating the effect of factors interactions on shop performance. Figure 3:(d) indicates insignificant effect of the interaction between CM and TBBD factors on



(a) (b)

(c) (d)

(e)

Figure 3: Mean flow time with factors interactions.

MFT but main effects of CM and TBBD still affects shop performance adversely at their high levels. Furthermore, by looking at Figure 3:(e) it is evident that the interaction between PTCV and TBBD factors affects MFT at both levels of the factors.

A representative sample of the results obtained is presented in Table 5. This sample result includes 32 combinations out of the 128 total combinations. The paired t-test performed showed that most of these combinations are significant at the 0.05 level. This indicates the effects on shop performance measures considered as a result of operating the cellular shop at different operating conditions. The relative difference in MFT for each pair of these operating conditions ranges between a maximum of 97% and a minimum of 8% increase.

5. Conclusion

This paper tries to investigate the effects of different operating conditions on the performance of a cellular shop. The results of this study indicate that the performance of cellular shops is affected by the level of job movements between shop cells, the level of grouping orders into transfer batches during the production process, the level of uncertainty in estimating the job processing times, the level of additional setup time required when jobs seek processing in cells other than their assigned cells, and the level of variability in the machine time between breakdowns. Furthermore, it was found that factor interactions have significant effects on the degree of impact of these factors on shop performance. Job mean flow time, work-in-process, with their standard deviations, which measure their variability, were found to correlated. This means that optimizing any one of them will yield to the optimization of the others. Although no specific conclusion and recommendation can be drawn and generalized for all cellular shop settings, it is highly recommended that operations managers should consider the effects of moving from regular shop setting into cellular shop setting taking into consideration all factors comprising their shop operating conditions and parameters. Moreover, worker training aiming toward better machine setup capability and machine maintainability performance is recommended. Computer system modeling and simulation with the available advanced computer technology represent an effective avenue for managers in this regard.

Levels of Factors						Collected Statistics		
Serial No	BS	PT	SI	TBBD	CM	Mean	Difference (%age)	P-value
1	L	L	L	L	L	78.6		
2	L	L	L	L	H	99.7	21.0 (16%)	0.030**
3	L	L	L	H	L	86.9		
4	L	L	L	H	H	100.9	14.0 (24%)	0.008**
5	L	L	H	L	L	78.6		
6	L	L	H	L	H	98.1	20.0 (14%)	0.041**
7	L	L	H	H	L	86.9		
8	L	L	H	H	H	99.8	12.9 (22%)	0.024**
9	L	H	L	L	L	108.3		
10	L	H	L	L	H	132.2	24.6 (22%)	0.028**
11	L	H	L	H	L	131.2		
12	L	H	L	H	H	155.8	24.6 (18%)	0.035**
13	L	H	H	L	L	115.8		
14	L	H	H	L	H	229.0	113.3 (97%)	0.014**
15	L	H	H	H	L	141.2		
16	L	H	H	H	H	264.4	123.2 (87%)	0.000**
17	H	L	L	L	L	64.9		
18	H	L	L	L	H	75.6	10.7 (16%)	0.015**
19	H	L	L	H	L	77.3		
20	H	L	L	H	H	83.7	6.4 (8%)	0.021**
21	H	L	H	L	L	64.9		
22	H	L	H	L	H	76.2	11.9 (17%)	0.020**
23	H	L	H	H	L	77.3		
24	H	L	H	H	H	87.4	10.1 (13%)	0.013**
25	H	H	L	L	L	100.5		
26	H	H	L	L	H	112.7	12.2 (12%)	0.121
27	H	H	L	H	L	118.0		
28	H	H	L	H	H	130.4	12.5 (10%)	0.037**
29	H	H	H	L	L	101.8		
30	H	H	H	L	H	124.2	20.6 (22%)	0.030**
31	H	H	H	H	L	120.5		
32	H	H	H	H	H	141.2	20.7 (17%)	0.030**

Legend:

BS =Batch size. PTCV=Processing time coefficient of variation.

SR = Setup index. TBBDCV= Time between breakdowns coefficient of variation.

CM= Inter-cell movement.

**: Means differ significantly if P-value < 0.05 at test significance level of $\alpha = 0.05$.

Table 5: Flow time means and their relative differences from means comparison t-test.

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Appendix

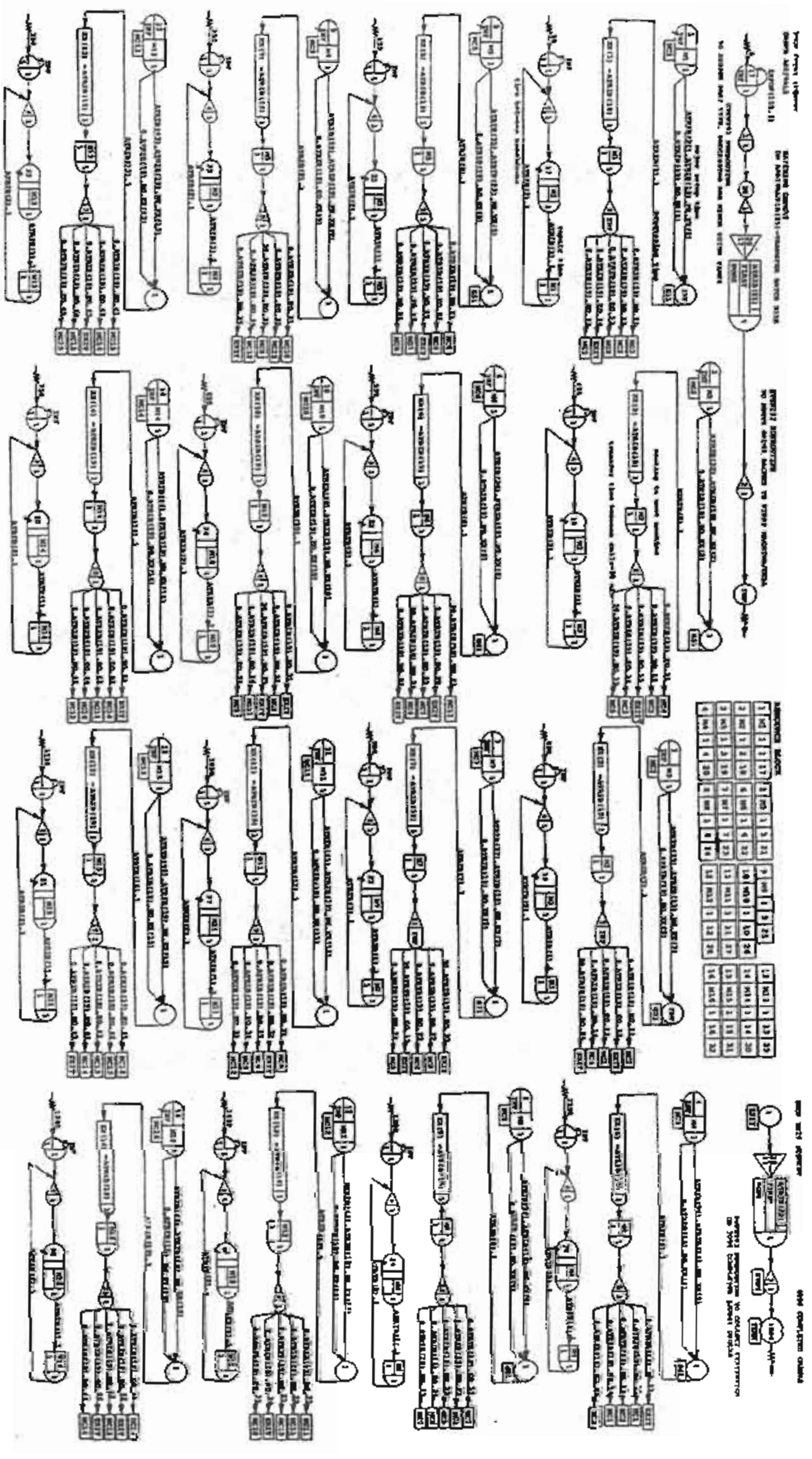
User's Insert Discrete Fortran Subroutine and SLAMII Network Model

```
      SUBROUTINE EVENT(I)
$INCLUDE:'PARAM.INC'
$INCLUDE:'SCOM1.COM'
     REAL TSYS, WIP, AVTSYS,STDFT,
     *AVWIP,STDWIP, F(4),FCUM(4),F1T(5),
     *PTMEAN,F2T(5),F3T(5),F4T(5),FTCUM(5),
     *AMEANR,SUMIN,SRM,
     *F1,F2,F3,F4,F5,BS,rmpt(5),RRMPT,
     *RSDPT(5),RRSDPT,RMWIP(5),RRMWIP,
     *RRSDWIP,RSDWIP(5)
     INTEGER NQ(16),JOBS, LLJOBS,
     *LUJOBS,ICN,IRUN
     DATA FCUM/.25,.50,.75,1.0/,FTCUM/.2,.4,.6,.8,1.0/
     DATA F/1,2,3,4/,F1T/11,12,13,14,15/,
     *F2T/21,22,23,24,25/
     DATA F3T/31,32,33,34,35/,F4T/,41,42,43,44,45/
C ** To adjust these factors for***
C ** each combination          ***
           IIRUN   =4
           F1      =2
           ICN      =20
           F2      =1
           F3      =1
           F4      =2
           F5      =2
C  ____________________________
         IF(F2.EQ.1)THEN
         BS=5
         ELSEIF(F2.EQ.2)THEN
         BS=30
         ENDIF
         IF(F4.EQ.1) THEN
         SRM=1.5
         ELSEIF(F4.EQ.2) THEN
         SRM=1.7
         ENDIF
C LLJOBS=WARMUP PERIOD.
C LUJOBS=COMPLETED ORDERS
         LLJOBS=500
         LUJOBS=1500
C set minor setup to 3 times
C  mean processing time (0.1 hr)
         SUMIN=0.3
C TO ASSIGN ORDER SIZE
C ATRIB(20)=60 UNITS
C BATCH SIZE  ATRIB(21)=5,30
C NO. OF BATCHES PER ORDER
C ATRIB(22)= 12, or 2
C BATCH PROCESSING TIME IN ATRIB(I)
C MAJOR SETUP TIME IN ATRIB(I+30)
C = SRM*ATRIB(I)
        ATRIB(20)=60
        ATRIB(21)=BS
        ATRIB(22)=ATRIB(20)/ATRIB(21)
C *** event codes 1,2,3,4,5,6,7,8,9,10,
C       11,12,13,14,15,16,17,18,19,20
C setup event for m/cs q1,q2,..,q16
C are 5,6,..,20 respectively.
```

```
       GO TO (1,2,3,4,5,6,7,8,9,10,11,
      *12,13,14,15,16,17,18,19,20), I
1      PTMEAN=0.1
       DO 101 I=1,16
       IF(F3.EQ.1)THEN
       ATRIB(I)=PTMEAN
       ELSEIF(F3.EQ.2) THEN
       ATRIB(I)=EXPON(PTMEAN,I)
       ENDIF
       ATRIB(I+30)=SUMIN
       ATRIB(I)=ATRIB(I)*ATRIB(21)
101    CONTINUE
      ATRIB(18)=DPROB(FCUM,F,4,2)
      IF(ATRIB(18).EQ.1.0) THEN
      ATRIB(19)=DPROB(FTCUM,F1T,5,3)
      ELSEIF(ATRIB(18).EQ.2.0) THEN
      ATRIB(19)=DPROB(FTCUM,F2T,5,4)
      ELSEIF(ATRIB(18).EQ.3.0) THEN
      ATRIB(19)=DPROB(FTCUM,F3T,5,5)
      ELSEIF(ATRIB(18).EQ.4.0) THEN
      ATRIB(19)=DPROB(FTCUM,F4T,5,6)
      ENDIF
      RETURN
2       IF(ATRIB(18).EQ.1) THEN
       IF(ATRIB(19).EQ.11) THEN
       CALL FILEM(1,ATRIB)
       ELSEIF(ATRIB(19).EQ.12) THEN
       CALL FILEM(4,ATRIB)
       ELSEIF(ATRIB(19).EQ.13) THEN
       CALL FILEM(4,ATRIB)
       ELSEIF(ATRIB(19).EQ.14) THEN
       CALL FILEM(2,ATRIB)
       ELSEIF(ATRIB(19).EQ.15) THEN
       CALL FILEM(1,ATRIB)
       ENDIF
       ELSEIF(ATRIB(18).EQ.2) THEN
       IF(ATRIB(19).EQ.21) THEN
       CALL FILEM(5,ATRIB)
       ELSEIF(ATRIB(19).EQ.22) THEN
       CALL FILEM(7,ATRIB)
       ELSEIF(ATRIB(19).EQ.23) THEN
       CALL FILEM(6,ATRIB)
       ELSEIF(ATRIB(19).EQ.24) THEN
       CALL FILEM(8,ATRIB)
       ELSEIF(ATRIB(19).EQ.25) THEN
       CALL FILEM(8,ATRIB)
       ENDIF
       ELSEIF(ATRIB(18).EQ.3) THEN
       IF(ATRIB(19).EQ.31) THEN
       CALL FILEM(12,ATRIB)
       ELSEIF(ATRIB(19).EQ.32) THEN
       CALL FILEM(10,ATRIB)
       ELSEIF(ATRIB(19).EQ.33) THEN
       CALL FILEM(11,ATRIB)
       ELSEIF(ATRIB(19).EQ.34) THEN
       CALL FILEM(10,ATRIB)
       ELSEIF(ATRIB(19).EQ.35) THEN
       CALL FILEM(11,ATRIB)
```

```
      ENDIF
      ELSEIF(ATRIB(18).EQ.4) THEN
      IF(ATRIB(19).EQ.41) THEN
      CALL FILEM(13,ATRIB)
      ELSEIF(ATRIB(19).EQ.42) THEN
      CALL FILEM(15,ATRIB)
      ELSEIF(ATRIB(19).EQ.43) THEN
      CALL FILEM(14,ATRIB)
      ELSEIF(ATRIB(19).EQ.44) THEN
      CALL FILEM(13,ATRIB)
      ELSEIF(ATRIB(19).EQ.45) THEN
      CALL FILEM(16,ATRIB)
      ENDIF
      ENDIF
      RETURN
3     JOBS=JOBS+1
      IF(JOBS.LE.LLJOBS) THEN
      RETURN
      ELSE
      TSYS=TNOW-ATRIB(17)
      CALL COLCT(TSYS,1)
      DO 31 I=1,16
      IF(NNQ(I).GT.0) THEN
      NQ(I)=NNQ(I)+1
      ELSE
      NQ(I)=NNQ(I)
      ENDIF
31    CONTINUE
      BWIP=0.0
      DO 23 I=1,16
      BWIP=BWIP+NQ(I)
23    CONTINUE
      WIP=BWIP*ATRIB(21)
      CALL COLCT(WIP,2)
      ENDIF
      IF(JOBS.EQ.LUJOBS) THEN
      AVTSYS=CCAVG(1)
      STDFT=CCSTD(1)
      AVWIP=CCAVG(2)
      STDWIP=CCSTD(2)
      TUT=0.0
      DO 201 I=1,16
      TUT=TUT+RRAVG(I)
201   CONTINUE
      AVGUT=TUT/16
      OPEN(5,FILE='C:\naswork.txt',STATUS='OLD')
      IF(NNRUN.EQ.1) THEN
      WRITE(5,53) ICN
53    FORMAT(1X,'Combination #',I3)
      ENDIF
      RMPT(NNRUN)=AVTSYS
      RSDPT(NNRUN)=STDFT
      RMWIP(NNRUN)=AVWIP
      RSDWIP(NNRUN)=STDWIP
      WRITE(5,55) F1,F2,F3,F4,F5, AVTSYS,STDFT,
     *AVWIP,STDWIP,AVGUT,Tnow
55    FORMAT(1X,5(F3.1,1X),F8.2,1X,
     *F8.2,1X,F8.2,1X,F8.2,1X,F8.2,1x,F8.2)
      IF(NNRUN.EQ.IIRUN) THEN
      WRITE(5,54)
54    FORMAT(1X,'Runs Means')
      DO 21 I=1,IIRUN
      RRMPT=RRMPT+RMPT(I)
      RRSDPT=RRSDPT+RSDPT(I)
      RRMWIP=RRMWIP+RMWIP(I)
      RRSDWIP=RRSDWIP+RSDWIP(I)
21    CONTINUE
      RRMPT=RRMPT/IIRUN
      RRSDPT=RRSDPT/IIRUN
      RRMWIP=RRMWIP/IIRUN
      RRSDWIP=RRSDWIP/IIRUN
     write(5,56) RRMPT, RRSDPT,
     * RRMWIP,RRSDWIP
56    format(4(1X,f8.2))
      ENDIF
```

```
      JOBS=0
      ENDIF
      RETURN
4      AMEAND=15.0
      AMEANR=1.0
      ATRIB(1)=AMEANR
      IF(F5.EQ.1) THEN
      ATRIB(2)=AMEAND
      ELSEIF(F5.EQ.2) THEN
      ATRIB(2)=EXPON(AMEAND,1)
      ENDIF
      RETURN
C TO ADJUST MAJOR SETUP
C OUTSIDE MACHINES
5      RETURN
6     IF(ATRIB(19).EQ.15) THEN
      ATRIB(35)=SRM*ATRIB(35)
      ELSEIF(ATRIB(19).EQ.45) THEN
      ATRIB(34)=SRM*ATRIB(34)
      ENDIF
      RETURN
7     IF(ATRIB(19).EQ.11) THEN
      ATRIB(43)=SRM*ATRIB(43)
      ENDIF
      RETURN
8     IF(ATRIB(19).EQ.24.0) THEN
      ATRIB(33)=SRM*ATRIB(33)
      ENDIF
      RETURN
9     IF(ATRIB(19).EQ.15.0) THEN
      ATRIB(37)=SRM*ATRIB(37)
      ENDIF
      RETURN
10    IF(ATRIB(19).EQ.21.0) THEN
      ATRIB(42)=SRM*ATRIB(42)
      ELSEIF(ATRIB(19).EQ.24.0) THEN
      ATRIB(34)=SRM*ATRIB(34)
      ENDIF
      RETURN
11    RETURN
12    IF(ATRIB(19).EQ.33.0) THEN
      ATRIB(37)=SRM*ATRIB(37)
      ENDIF
      RETURN
13    IF(ATRIB(19).EQ.33.0) THEN
      ATRIB(38)=SRM*ATRIB(38)
      ENDIF
      RETURN
14    IF(ATRIB(19).EQ.42) THEN
      ATRIB(39)=SRM*ATRIB(39)
      ENDIF
      RETURN
15    RETURN
16    IF(ATRIB(19).EQ.21.0) THEN
      ATRIB(40)=SRM*ATRIB(40)
      ELSEIF(ATRIB(19).EQ.35) THEN
      ATRIB(44)=SRM*ATRIB(44)
      ENDIF
      RETURN
17    IF(ATRIB(19).EQ.11) THEN
      ATRIB(45)=SRM*ATRIB(45)
      ELSEIF(ATRIB(19).EQ.42) THEN
      ATRIB(40)=SRM*ATRIB(40)
      ENDIF
      RETURN
18    IF(ATRIB(19).EQ.45) THEN
      ATRIB(32)=SRM*ATRIB(32)
      ELSEIF(ATRIB(19).EQ.35) THEN
      ATRIB(46)=SRM*ATRIB(46)
      ENDIF
      RETURN
19     RETURN
20    RETURN
      END
```



SLAM II network model for the cellular shop.