Evaluation of dynamic and static dispatching strategies for dynamically planned and unplanned flexible manufacturing systems

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Scheduling, in Flexible Manufacturing systems (FMSs), differs from that conventional job shop because any one of several machines may perform each operation of a job. In this work, the considered dispatching rules are studied for FMSs under the condition that the part types and their quantities are dynamically changed over some specified stages or periods of the entire scheduled horizon. SIMFACTORY II.5 is used to animate twelve dispatching rules under the aimed strategies. The analysis of the obtained results showed that an overall improvement could be achieved for dynamic dispatching than that rendered by static dispatching.

ان استراتيجيات نظم دفع المنتجات تلعب دور كبير وهام في نظم التصنيع المرنة وتؤثر بشكل فعال على مستوى أداء هذه المنظومات الصناعية. فى هذا البحث تمت دراسة استراتيجيات دفع المنتجات فى نظم التصنيع المرنة عندما تكون استراتيجيات الدفع في وضع ديناميكي يتغير مع تغيير حجم ونوع الإنتاج وكذلك تمت دراسة استراتيجيات الدفع في الحالة الاستاتيكية. وباستخدام أحد البرامج الجاهزة واختبار عدة طرق للدفع تم قياس مستوى الأداء في كل من الحالتين ووجد أن قواعد الدفع المتغيرة ديناميكيا تعطى نتائج افضل من استخدام قواعد الدفع الاستاتيكية وان التخطيط لتفعيل هذه القواعد هو افضل من عدم التخطيط له كما أن معدل منفعة الموارد في الحالة الديناميكية هو افضل من الحالة الاستاتيكية.

Keywords: Dispatching rules, Flexible manufacturing systems, FMS scheduling, Simulation

1. Introduction

Scheduling plays a crucial role in the efficiency of any production system. The emergency of flexible manufacturing system (FMS) has sparked an increased interest and appreciation of real time planning, scheduling and control. FMS is defined as a manufacturing system consisting of automatically reprogrammable machines, automated tool deliveries and changes, automated material handling and transport, and coordinated shop floor control.

In the past two decades, many researchers have tried to evaluate the performance of dispatching rules in a dynamic manufacturing systems. A learning-based methodology for dynamic scheduling that explores flexibility and handles uncertainties in distributed manufacturing system is developed by Chiu and Yih [1].

An extended dispatching rule approach, which applies different dispatching rule combinations in the mechanisms, and a search algorithm to find an appropriate dispatching rule combination has been advised by Ishii and Muraki [2].

A new shop-based and predictive scheduling heuristic for cellular manufacturing has been developed by Mahmoodi and Martin [3]. This heuristic includes a feature for dynamically assessing variations in a sub-family's arrival rate, enhancing suitability for realistic transient-state conditions as well as minimizing aggregate times required for major sequence-dependent machine set-ups at work center.

A decision rule for real-time dispatching of parts, each of which may have alternative processing possibilities, has been developed by Chandra and Talavage [4]. For effective use of the system's routing flexibility, an intelligent part-selection strategy that takes into account the current trends of the system has been designed. The proposed intelligent reasoning procedure has been found to achieve better shop performance than some of the popular dispatching rules, the improved performance being due to the ability to response to changing circumstances.

An intelligent control scheme has been presented by Seifert and Morito [5] for releasing parts into a flexible manufacturing system that is based on incremental optimization. The intelligent release mechanism of some look-ahead and optimization features in order to guarantee the cooperation of work centers. The cooperative dispatching concept is implemented in an object-oriented computer simulation model, and experiments with a varying degree of average routing flexibility are performed. The resulted analysis verified the robustness of the presented FMS control scheme in case of random machine breakdowns.

A combined scheduling approach with machine layout problems in flexible manufacturing system is introduced by Potts and Whitehead [6]. In this model, the machines have the capability of performing several different types of operations. Each operation type is assigned to only one of the machines, which are positioned around a unidirectional conveyor belt loop. In this model, the throughput is maximized by balancing and minimizing bottleneck workload. Minimization of the movement of work between machines has been achieved by three-phase integer programming model. The output results are promising.

Two models for evaluating some operation control rules in scheduling functional and cellular FMS and in the presence of work center interruptions are introduced by Shouman et al. [7,8]. In these models, a combined routing, planned, unplanned interruption ratios and different dispatching mechanisms are considered. The models are used to evaluate different configurations of the systems under consideration. Mathematical formulations for the expected due date based on the model configuration and good performance achievements have been derived.

Basically, there are two approaches to solve the problem of switching to proper dispatching rules in manufacturing systems; a look-ahead simulation approach and a knowledge-based approach. For the look-ahead simulation approach, a dispatching rule is determined for each short period just before the implementation time occurs. For the knowledge-based approach [9], the scheduling of changing dispatching rules is first acquired, and then this knowledge is incorporated into an expert system to guide a manufacturing system to make intelligent decisions in real time.

In this work, the considered dispatching rules are studied for FMSs under the condition that the part types and their quantities are dynamically changed over some specified stages or periods of the whole scheduled horizon. Two different phases are considered for the study in this work. In the first phase, the part types with their relative demands are dynamically changed at deterministic dates over the whole scheduled period. This means that the dynamic changes are planned in their occurrences, while in the second phase, the part types are dynamically changed at undeterministic dates. In such case, the dynamic changes are unplanned in their occurrences.

2. Model assumptions and description

2.1 Model assumptions

For the planned and unplanned cases, the overall scheduled period is basically classified into stages according to the dynamic changes. The throughput of a certain specified part type may be distributed on different stages or single one under the constraint that the first appearance will be in the corresponding stage of their production orders or succeeding stages. In order to make a general comparison between the planned and unplanned conditions it is assumed that the interbreak points are identical for both cases under consideration.

For the look-ahead simulation approach, which is followed in this work, a dispatching rule is determined for each short period. The combination of different dispatching rules in a dynamic and multi-pass manner will create better result than applying a single rule in a static manner. The best dispatching rule selected from the set of candidate rules is identified by simulation, that is controlled by objective function, part mix, and performance measures.

Moreover, the model is configured based on the following assumptions:

1. Each part type consists of one or more operation(s).
2. There are one or more machine(s) which can process each operation and each machine can process one operation at a time.
3. The part moving time is assumed not to affect the lead time.
4. System congestion, is assumed to be prevented by limiting the total service time of each machine station to the capacity of that station.
5. Tool change-over times are included in processing time and tool magazine capacities are not binding constraints due to the availability of an automatic tool handling system.
6. Data on all alternative routes and processing times can be provided.
7. Arrival rates, due dates, transporter speed, resources, set-up and tear down times are deterministic.
8. Each operation can be processed by one machine only at a time.
9. Transporters are assumed to be sized by the parts.

2.2. Model description

The model consists of eight machines (M/C1, M/C2, M/C3, M/C4, M/C5, M/C6, M/C7, and M/C8) each of which has a storage buffer (BF1, BF2, BF3, BF4, BF5, BF6, BF7 and BF8). The model has a receiving area, two load/ unload stations (LOAD, LOAD1). Parts enter and leave the FMS at load/ unload stations and transferred between machine centers by the aids of the available truck of the system. Fig. 1 exhibits the physical layout together with the transfer network. Eight distinct part types to be processed within the proposed model (P1, P2, P3, P4, P5, P6, P7 and P8). Part types P1, P2, P3, and P4 enter and exit the model at LOAD station, while P5, P6, P7 and P8 enter and exit the model at LOAD1 station. Each part type requires several operations. The processing times, operations required, and due dates for part types are listed in table 1. The possible routes through the system, and the arrival times for each part type are also shown in table 1.

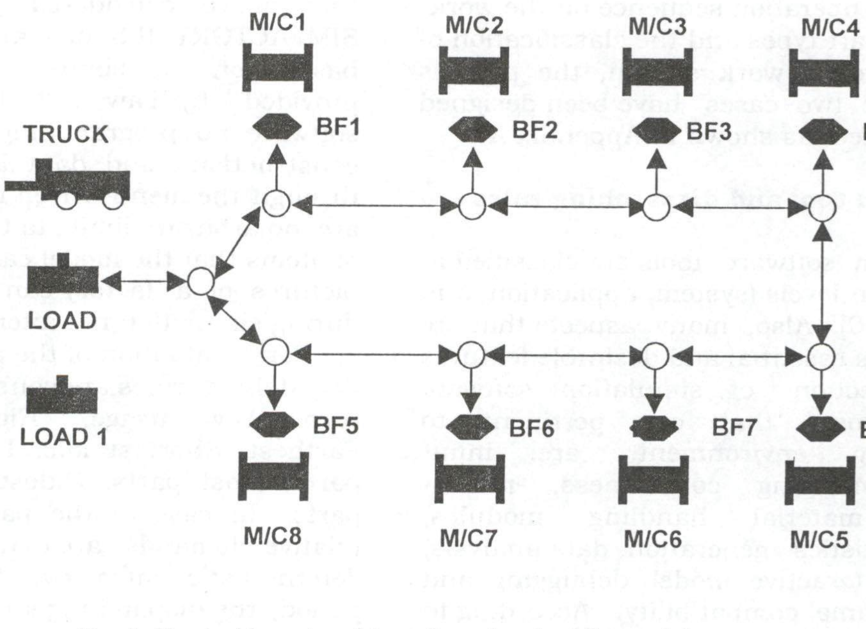

Fig. 1. Physical layout and transfer network of the model.

Table 1
Operation specifications, available routes, sequence, and due dates

Part Type										Due date (min)	Arrival time	Quantity
P1(1st Stage)	Operation Req.	OPA1	OPA2	OPA3	OPA4	OPA5	OPA6					
	Processing time	3	5	4	6	5	4			1300	100	55
	Machine No.	1	3	4	6	2	2					
P2(1st stage)	Operation Req.	OPB1	OPB2	OPB3	OPB4	OPB5	OPB6					
	Processing time	1	4	3	4	6	8			1350	100	75
	Machine No.	4	7	6	1	3	5					
P3(2nd stage)	Operation Req.	OPC1	OPC2	OPC3	OPC4	OPC5	OPC6	OPC7	OPC8			
	Processing time	4	3	2	4	5	5	1	6	2400	1060	55
	Machine No.	6	8	2	3	5	1	7	4			
P4(2nd stage)	Operation Req.	OPD1	OPD2	OPD3	OPD4							
	Processing time	3	3	3	4					1500	1060	75
	Machine No.	3	1	6	8							
P5(3rd stage)	Operation Req.	OPE1	OPE2	OPE3	OPE4	OPE5						
	Processing time	1	2	4	5	7				1800	2020	55
	Machine No.	6	5	1	2	7						
P6(3rd stage)	Operation Req.	OPF1	OPF2	OPF3	OPF4	OPF5	OPF6					
	Processing time	4	3	2	1	4	5			1600	2020	75
	Machine No.	1	3	2	5	6	4					
P7(4th stage)	Operation Req.	OPH1	OPH2	OPH3	OPH4	OPH5	OPH6	OPH7				
	Processing time	5	4	3	8	1	2	4		900	2980	55
	Machine No.	5	3	2	1	6	8	4				
P8(4th stage)	Operation Req.	OPI1	OPI2	OPI3	OPI4	OPI5						
	Processing time	2	4	4	8	7				900	2980	75
	Machine No.	2	5	3	8	6						

Based on the operation sequence on the work-stations for part types and the classification of operations/ each work station, the process plans for the two cases have been designed and constructed, as shown in Appendix A.

3. Simulation tool and dispatching rules

Simulation software tools are classified at three different levels (system, application, and structural) [10]. Also, many aspects that are considered as essential and desirable features in the selection of simulation software product. Those, that are pertinent to manufacturing environment, are: input flexibility, modeling conciseness, macro-capability, material handling modules, standard statistics generation, data analysis, animation, interactive model debugging, and micro/mainframe compatibility. According to the above considered groups of criteria, SIMFACTORY II.5 has an advanced position based on a simulation software survey provided by Law and Haider [11]. In this, software no programming is required, model construction and data input are simplified through the menu-driven interface. Also, there are no arbitrary limits to the number and type of items that the model can include. Animated pictures of a factory can be obtained at work during simulation not after the action is over.

For evaluation of the present work, twelve dispatching rules are considered; Random, By turn, Low usage, High usage, Closest, Farthest, Shortest idle, Longest idle, Fewest parts, Most parts, Oldest parts and Newest parts. In case of the part types with their relative demands are dynamically changed at deterministic dates over the whole scheduled period, the dispatching strategies will be static at the inter break points over the whole scheduled period. When the part types are dynamically changed at undeterministic dates, the dispatching strategies under consideration will be dynamically changed at the inter break points over the remainder horizon of scheduled period.

4. Description of model experiments

4.1. Model implementation

The designed transferred networks connecting the subsystems of material handling under consideration is exhibited in Figure 1. Based on the operation sequence on the work-stations for part types and the classification of operations/ each work station, the process plans for the two cases have been designed and constructed. The complete data information for this model, as well as the process plans are addressed in SIMFACTORY II.5 and verified through its verification procedure. Many simulation runs have been carried out for each dispatching rule/ each case, till it reach to stable state or the average values for the most stable station will be considered, as discussed in the following sections.

4.2. Pattern of arrival

The pattern of arrival for both planned and unplanned cases is considered as a scheduled pattern with the arrival times of part types exhibited in table 1. Four stages are considered for both planned and unplanned models. Different data files are attained in the simulation process for different dispatching strategies for both planned and unplanned models.

As cited before both planned and unplanned cases consist of four stages as a planning horizon. P1, P2, P3, P4, P5, P6, P7, and P8 are entered the system in consecutive pairs in the corresponding arrival times, and stages which are presented in table 1. The scenario of simulation will held unchanged for all the considered stages under consideration in unplanned case while the number of replications will be increased from stage to another in the planned case. This increasing is in the aim of achieving the same scenario configurations with unplanned case. The first stage has no breakpoints. The second stage has single breakpoint to enter P3 and P4, while the third stage has dual breakpoints to enter P3, P4, P5, and P6 in pairs, respectively. In fourth stage, three breakpoints are existing. The third one is for P7 and P8.

5. Measuring performance criteria

Simulation output provides the scalar of the simulator with a performance measure, which quantifies the performance of the simulated model. A few important equivalence in performance measures applied in this work: throughput rate, product make span, mean flow time (MFT), mean tardiness (MT), sum of mean flow time and mean tardiness, and number of tardy jobs (TJ). These measuring performance criteria are considered for the evaluation of dispatching mechanisms for each model configuration in order to determine the dispatching rule that will perform the best. In the case, when throughput and product make span will be insignificant parameters for evaluation; MFT, MT, sum of both, and number of tardy jobs will be considered. MFT and MT are estimated as in eq. (1) and (2):

$$\text{Mean flow time} = \Sigma\,(C_i - R_i)/n, \tag{1}$$

$$\text{Mean tardiness} = \Sigma \max\,(0, L_i)\;/\;NT. \tag{2}$$

Where C_i is the completion time of part i, R_i is the time of entry, D_i is the due date of part i, NT is the number of tardy jobs, L_i is the lateness of part i ($C_i - R_i - D_i$), and n is number of completed parts.

6. Experimental results and evaluation

Twelve dispatching rules were simulated to study the impact of the system design parameters for the estimate of each short time period (stage) of the whole scheduled horizon. According to the performance criteria, the best dispatching mechanism will be considered for this short time period. The design parameters were systematically changed for each policy and simulation runs including the relative break point were carried out. This procedure is systematically continued until the whole horizon is scheduled. However, many simulation runs have been performed till the results will be stable and then recorded.

6.1. Unplanned case

In this model, the inter-break points are fed at the specified duration. The throughput, product make-span, and tracing messages have been recorded. Table 2 lists both the throughput and product make span for the best dispatching rule at each stage of the scheduling horizon. According to the considered performance criteria both the throughput and product make span are ranked as the most critical priority orders in the evaluation process.

In this case, the best dispatching rule obtained for stage i has been tested for the other remaining stages i + n, where n represents the remaining stages of the whole scheduled horizon. Hence, By turn is tested for 2nd, 3rd and 4th stages, Low usage is tested for 3rd and 4th stages and By turn is tested for fourth stage.

In case of considering MFT, MT, MFT + MT, and number of tardy jobs as measuring performance criteria in evaluation, table 3 presents throughput, make span in addition to these measuring performance criteria for the simulation tests with the best schedule obtained for the considered model. The utilization of machines and resources of simulation results are also recorded and exhibited in figs. 2 and 3.

Table 2
Throughput and make span for planned and unplanned case

Unplanned case			Planned case		
Stage	Throughput	Make span	Stage	Throughput	Make span
By turn	16.250	23.71750	By turn	45.750	66.190
1st Stage (Rule 1)			1st Stage (Rule 1)		
Low usage	32.500	24.1550	Low usage	48.625	40.020
2nd Stage (Rule 2)			2nd Stage (Rule 2)		
By turn	48.750	84.7942	Low usage	51.260	58.400
3rd Stage (Rule 3)			3rd Stage (Rule 3)		
Fewest parts	54.935	74.4794	Farthest parts	54.995	81.591
4th Stage (Rule 4)			4th Stage (Rule 4)		

Table 3
Measuring performance criteria of simulation tests for unplanned and planned case

Stages	Throughput	Make span	MFT	MT	MFT+MT	TJ
1st stage(up)	54.935	82.090625	906.44	75.386130	981.82858	33
2nd stage(up)	54.935	81.523125	897.46	73.588040	971.04540	31
3rd stage(up)	54.870	80.754875	898.75	74.300415	973.051565	28.5
4th stage(up)	54.935	74.429370	899.05	75.833000	974.879000	29
1st stage(p)	54.995	81.1038	903.0	77.9546	980.98306	30
2nd stage(p)	54.810	82.3112	907.0	70.0615	977.08280	36
3rd stage(p)	54.745	83.2156	902.4	67.5787	970.00373	30
4th stage(p)	54.955	81.5938	907.8	72.6852	980.54405	35.5

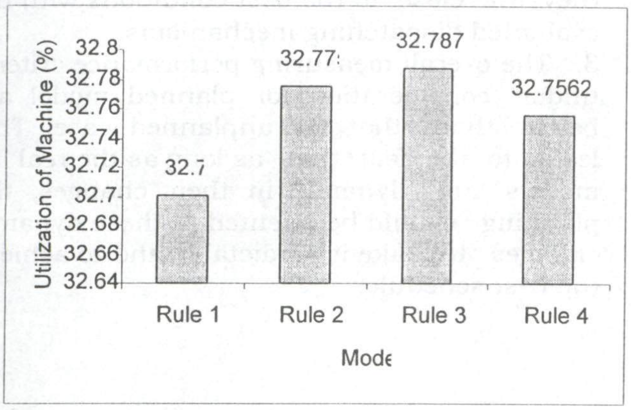

Fig. 2. Machine utilization of simulation tests for the unplanned case.

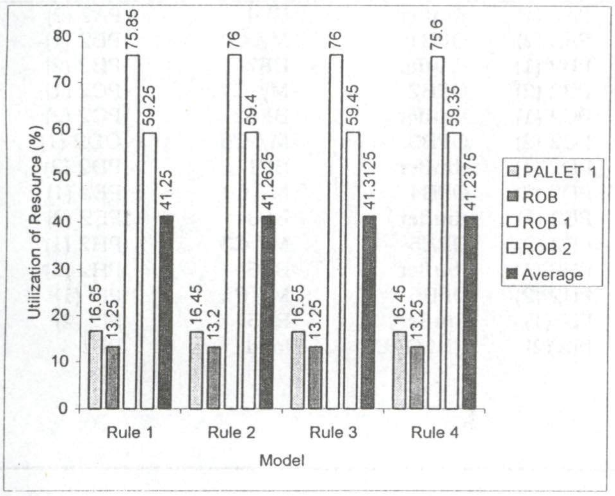

Fig. 3. Resource utilization of simulation tests for the unplanned case.

6.2. Planned case

In this model, the inter-break points are feed at the specified duration. The throughput, product make span, tracing information have been recorded. Table 2 lists both the throughput and product make span for the best dispatching rule at each stage of the scheduling horizon. According to the considered performance criteria, both the throughput and the product make span are ranked as the most critical priority orders in the evaluation process.

In this case, the simulation process has been implemented without break points for the specified dispatching rules under consideration for scheduling process in the system for all the considered time periods (i.e. no change in dispatching mechanisms all over the stages) in order to compare these results with that obtained by the proposed scheme.

Also, the best dispatching rule obtained for stage i has been tested for the other remaining stages i + n of the simulated model, where n represents the remaining stages of the scheduled horizon. In case of considering MFT, MT, MFT + MT, and number of tardy jobs as measuring performance criteria in evaluation, table 3 presents throughput and make span in addition to these measuring performance criteria for the simulation tests with best schedule obtained for the considered model. The utilization of machines and resources of simulation results are also, recorded and exhibited in figs. 4 and 5.

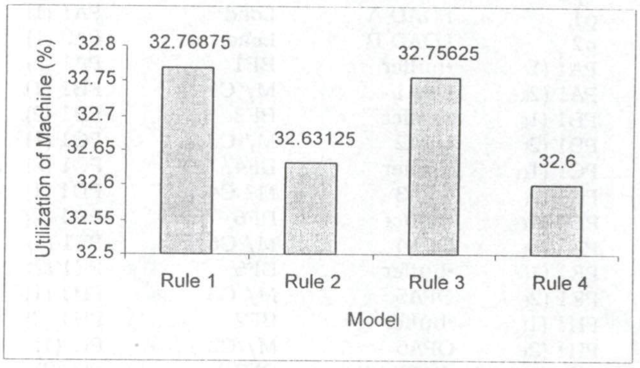

Fig. 4. Machine utilization of simulation tests for the planned case.

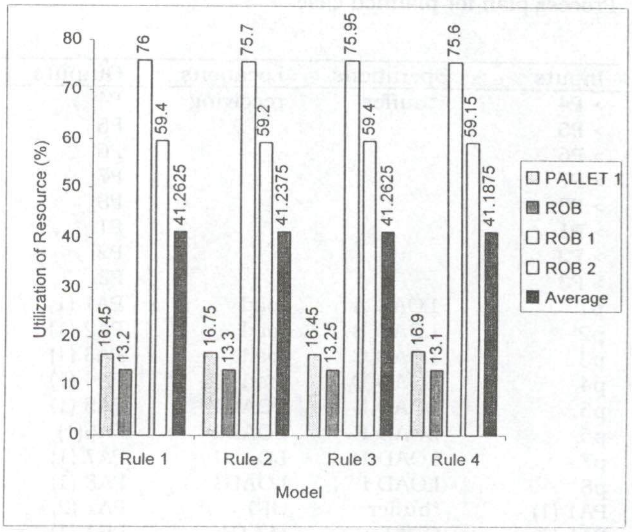

Fig. 5. Resource utilization of simulation tests for the planned case.

7. Conclusions

From the through investigation of the obtained results, the following conclusions can be highlighted:

1. An overall improvements (throughput, make span) have been achieved for a dynamic dispatching schedule than that obtained in static dispatching schedule.
2. Both machines and resources utilization are not the best for the best schedule, but they are close to the best conditions with the evaluated dispatching mechanisms.
3. The overall measuring performance criteria under consideration for planned model are better than that for unplanned case. This leads to the fact that as long as the real life models are dynamic in their changes, the planning should be oriented to these dynamic changes to make it predictable and to achieve the best schedule.

Appendix A-1

Table A-1
Process plan for unplanned case

Inputs	Operations	Locations	Outputs	Inputs	Operations	Locations	Outputs
<p1	•buffer	RECEIVING	P1	PA2 (1)	•buffer	BF4	PA2 (2)
<p2			P2	PA2 (2)	OPB1	M/ C4	PB2 (1)
p1	LOAD A	Load	PA1 (1)	PB2 (1)	•buffer	BF7	PB2 (2)
p2	LOAD B	Load	PA2 (1)	PB2 (2)	OPB2	M/ C7	PC2 (1)
PA1 (1(	•buffer	BF1	PA1 (2)	PC2 (1)	•buffer	BF6	PC2 (2)
PA1 (2(	OPA1	M/ C1	PB1 (1)	PC2 (2)	OPB3	M/ C6	OD2 (1)
PB1 (1(	•buffer	BF3	PB1 (2)	PD2 (1)	•buffer	BF1	PD2 (2)
PB1 (2(	OPA2	M/ C3	PC1 (1)	PD2 (2)	OPB4	M/ C1	PE2 (1)
PC1 (1(	•buffer	BF4	PC1 (2)	PE2 (1)	•buffer	BF3	PE2 (2)
PC1 (2(	OPA3	M/ C4	PD1 (1)	PE2 (2)	OPE5	M/ C3	PH2 (1)
PD1 (1(	•buffer	BF6	PD1 (2)	PH2 (1)	•buffer	BF5	PH2 (2)
PD1 (2(	OPA4	M/ C6	PE1 (1)	PH2 (2)	OPB6	M/ C5	PI2 (1)
PE1 (1(	•buffer	BF5	PE1 (2)	PI2 (1)	•buffer	BF5	PI2 (2)
PE1 (2(	OPA5	M/ C5	PH1 (1)	PI2 (2)	UNLOAD2	load	PF2
PH1 (1(	•buffer	BF2	PH1 (2)				
PH1 (2(	OPA6	M/ C2	PI1 (1)				
PI1 (1(	•buffer	BF2	PI1 (2)				
PI1 (2(	UNLOAD1	Load	PF1				

Table A-2
Process plan for planned case

Inputs	Operations	Locations	Outputs	Inputs	Operations	Locations	Outputs
> P4	*buffer	receiving	P4	PD4 (1)	*buffer	BF8	PD4 (2)
> P5			P5	PD4 (2)	OPD4	M/ C8	PE4 (1)
> P6			P6	PE4 (1)	*buffer	BF8	PE4 (2)
> P7			P7	PE4 (2)	UNLOAD4	load	PF4
> P8			P8	PA5 (1)	*buffer	BF6	PA5 (2)
> P1			P1	PA5 (2)	OPE1	M/ C6	PB5 (1)
> P2			P2	PB5 (1)	*buffer	BF5	PB5 (2)
> P3			P3	PB5 (2)	OPE2	M/ C5	PC5 (1)
p1	LOAD A	load	PA1 (1)	PC5 (1)	*buffer	BF1	PC5 (2)
p2	LOAD B	load	PA2 (1)	PC5 (2)	OPE3	M/ C1	PD5 (1)
p3	LOAD C	load	PA3 (1)	PD5 (1)	*buffer	BF2	PD5 (2)
p4	LOAD D	load	PA4 (1)	PD5 (2)	OPE4	M/ C2	PE5 (1)
p5	LOAD E	LOAD1	PA5 (1)	PE5 (1)	*buffer	BF7	PE5 (2)
p6	LOAD F	LOAD1	PA6(1)	PE5 (2)	OPE5	M/ C7	PH5 (1)
p7	LOAD H	LOAD1	PA7 (1)	PH5 (1)	*buffer	BF7	PH5 (2)
p8	LOAD I	LOAD1	PA8 (1)	PH5 (2)	UNLOAD5	LOAD1	PF5
PA1 (1)	*buffer	BF1	PA1 (2)	PA6 (1)	*buffer	BF1	PA6 (2)
PA1 (2)	OPA1	M/ C1	PB1 (1)	PA6 (2)	OPF1	M/ C1	PB6 (1)
PB1 (1)	*buffer	BF3	PB1 (2)	PB6 (1)	*buffer	BF3	PB6 (2)

Table A-2 (Cont.)

Inputs	Operations	Locations	Outputs
PB1 (2)	OPA2	M/ C3	PC1 (1)
PC1 (1)	*buffer	BF4	PC1 (2)
PC1 (2)	OPA3	M/ C4	PD1 (1)
PD1 (1)	*buffer	BF6	PD1 (2)
PD1 (2)	OPA4	M/ C6	PE1(1)
PE1 (1)	*buffer	BF5	PE1 (2)
PE1 (2)	OPA5	M/ C5	PH1 (1)
PH1 (1)	*buffer	BF2	PH1 (2)
PH1 (2)	OPA6	M/ C2	PI1 (1)
PI1 (1)	*buffer	BF2	PI1 (2)
PI1 (2)	UNLOAD1	load	PF1
PA2 (1)	*buffer	BF4	PA2 (2)
PA2 (2)	OPB1	M/ C4	PB2 (1)
PB2 (1)	*buffer	BF7	PB2 (2)
PB2 (2)	OPB2	M/ C7	PC2 (1)
PC2 (1)	*buffer	BF6	PC2 (2)
PC2 (2)	OPB3	M/ C6	PD2 (1)
PD2 (1)	*buffer	BF1	PD2 (2)
PD2 (2)	OPB4	M/ C1	PE2 (1)
PE2 (1)	*buffer	BF3	PE2 (2)
PE2 (2)	OPB5	M/ C3	PH2(1)
PH2 (1)	*buffer	BF5	PH2 (2)
PH2 (2)	OPB6	M/ C5	PI2 (1)
PI2 (1)	*buffer	PF5	PI2 (2)
PI2 (2)	UNLOAD2	load	PF2
PA3 (1)	*buffer	BF6	PA3 (2)
PA3 (2)	OPC1	M/ C6	PB3 (1)
PB3 (1)	*buffer	BF8	PB3 (2)
PB3 (2)	OPC2	M/ C8	PC3 (1)
PC3 (1)	*buffer	BF2	PC3 (2)
PC3 (2)	OPC3	M/ C2	PD3 (1)
PD3 (1)	*buffer	BF3	PD3 (2)
PD3 (2)	OPC4	M/ C3	PE3 (1)
PE3 (1)	*buffer	BF5	PE3 (2)
PE3(2)	OPC5	M/ C5	PH3 (1)
PH3 (1)	*buffer	BF1	PH3 (2)
PH3 (2)	OPC6	M/ C1	PI3 (1)
PI3 (1)	*buffer	BF7	PI3 (2)
PI3 (2)	OPC7	M/ C7	PJ3 (1)
PJ3 (1)	*buffer	BF4	PJ3 (2)
PJ3 (2)	OPC8	M/ C4	PL3 (1)
PL3 (1)	*buffer	BF4	PL3 (2)
PL3 (2)	UNLOAD3	load	PF3
PA4 (1)	*buffer	BF3	PA4 (2)
PA4 (2)	OPD1	M/ C3	PB4 (1)
PB4 (1)	*buffer	BF1	PB4 (2)
PB4 (2)	OPD2	M/ C1	PC4 (1)
PC4 (1)	*buffer	BF6	PC4 (2)
PC4 (2)	OPD3	M/ C6	PD4 (1)
PB6 (2)	OPF2	M/ C3	PC6 (1)
PC6 (1)	*buffer	BF2	PC6 (2)
PC6 (2)	OPF3	M/ C2	PD6 (1)
PD6 (1)	*buffer	BF5	PD6 (2)
PD6 (2)	OPF4	M/ C5	PE6 (1)
PE6 (1)	*buffer	BF6	PE6 (2)
PE6 (2)	OPF5	M/ C6	PH6 (1)
PH6 (1)	*buffer	BF4	PH6 (2)
PH6 (2)	OPF6	M/ C4	PI6 (1)
PI6 (1)	*buffer	BF4	PI6 (2)
PI6 (2)	UNLOAD6	LOAD1	PF6
PA7 (1)	*buffer	BF5	PA7 (2)
PA7 (2)	OPH1	M/ C5	PB7 (1)
PB7 (1)	*buffer	PF3	PB7 (2)
PB7 (2)	OPH2	M / C3	PC7 (1)
PC7 (1)	*buffer	PF2	PC7 (2)
PC7 (2)	OPH3	M / C2	PD7 (1)
PD7 (1)	*buffer	PF1	PD7 (2)
PD7 (2)	OPH4	M / C1	PE7 (1)
PE7 (1)	*buffer	PF6	PE7 (2)
PE7 (2)	OPH5	M / C6	PH7 (1)
PH7 (1)	*buffer	PF8	PH7 (2)
PH7 (2)	OPH6	M / C8	PI7 (1)
PI7 (1)	*buffer	BF4	PI7 (2)
PI7 (2)	OPH7	M/ C4	PJ7 (1)
PJ7 (1)	*buffer	BF4	PJ7 (2)
PJ7 (2)	UNLOAD7	LOAD1	PF7
PA8 (1)	*buffer	BF2	PA8 (2)
PA8 (2)	OPI1	M/ C2	PB8 (1)
PB8 (1)	*buffer	BF5	PB8(2)
PB8 (2)	OPI2	M/ C5	PC8 (1)
PC8 (1)	*buffer	BF3	PC8 (2)
PC8 (2)	OPI3	M/ C3	PD8 (1)
PD8 (1)	*buffer	BF8	PD8 (2)
PD8 (2)	OPI4	M/ C8	PE8 (1)
PE8 (1)	*buffer	BF6	PE8 (2)
PE8 (2)	OPI5	M/ C6	PH8 (1)
PH8 (1)	*buffer	BF6	PH8 (2)
PH8 2)	UNLOAD8	LOAD1	PF8

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