A New Concept of Cellular Manufacturing: A Case Study

Jainarine Bansee[1], Boppana V. Chowdary[2]
[1]The University of Trinidad & Tobago, Pt. Lisas, Trinidad & Tobago, West Indies, jainarine_bansee@yahoo.com
[2]The University of the West Indies, St Augustine, Trinidad & Tobago, West Indies, chowdary@eng.uwi.tt

ABSTRACT

The manufacturing sector has become increasingly competitive as markets become more globalized. Consequently, there have been major shifts in the design of manufacturing systems using innovative concepts. The adoption of cellular manufacturing (CM) has received considerable interest from both practitioners and academicians that offers several major advantages, including reduction in lead times and work-in-process inventories, and reduction of setup times due to similarity of part types produced. Reorganizing the cell layout to meet the changed needs, however, may be time-consuming and costly. Further, if these changes occur very frequently, reconfiguration becomes impracticable or even infeasible. In such an environment, it appears that manufacturers tend to adopt a traditional job shop layout combined with the benefits of cellular manufacturing systems.

The research in this paper considers the new concept of virtual cellular manufacturing (VCM). This is in an attempt to increase the efficiency of manufacturing operations by varying the methods of production. Embedded in this paper are the principles of group technology (GT) as it applies to processing families of parts that have similar manufacturing operations. The problem of family oriented scheduling to take further set-up efficiencies of traditional CM that combines with the routing flexibility of a functionally organized job shop is also entrenched. Decisions for pooling of jobs into families, release of part families to the shop and dispatching of jobs to individual machines will lead to further improvement in job flow time. In this paper a case study was used to demonstrate new concept of CM. Emphasis will be placed to compare the model performance in terms of set-up and job flow times.

Keywords: Group Technology, Cellular manufacturing, Virtual Cell Formation, Plant Design

1. INTRODUCTION

Due to the ease with which global information is available to the customer their requirement for goods and services (G&S) are of a high standard. These G&S must be easily available with short lead time at very competitive prices. This is evident within the manufacturing industry in Trinidad and Tobago (T&T).

The varieties of products which are produced in the manufacturing industries within T&T are done using various processes and are accomplished through operations such as, Job Shop (JS), Flow Shop, Project and Continuous. In an environment where the customer demands are of small quantities from a large variety, the JS operation becomes critical.

Within the JS environment as evident by local manufacturers their customers are not satisfied. This is a result of problems which exist at these companies both at the management and operational levels which were obtained from various field visits to these firms and are now listed below.

Management Issues:

- There is no documented or adopted policy that is strictly followed in terms of job scheduling.
- No plan replacement and upgrades of machinery.

- No scientific maintenance programs for plant and machinery.
- Lack of training pertaining to new operational techniques and upgrade of skills.
- No plan succession program for continuity of effective and efficient operations.
- Low employee moral due to lack of motivation and compensation.

Operational Issues:

- Due to the methods of material handling and the arrangement of the JS, delays in movement of materials occur.
- The time taken to set-up jobs on the machines is a considerable amount resulting in further delays.
- While set-up of jobs is taking place the machines are not in use resulting in idle time of machines.
- When machines are idle while set-up is taking place large queues are formed with jobs waiting to be processed which leads to high work-in-process.
- The summation of these delays leads to a high flow time and low system utilization.

By an examination of the above problems one critical element that is recurring at the operational level is delays which were also highlighted previously by others (Suresh, 1991). Then, the question is how these process delays can be reduced. Due to the large variety of jobs and based on an average most of the time delays occur during the job set-up stage. Then, the next question is how these set-up times can be reduced within a JS environment. In this paper an undertaking was done to rectify the problems at the operational level. Specifically to reduce the processing delays at all the stages by varying the methods of production at minimal cost and interruption to the manufacturers.

The format of this paper is as follows. Section 2 deals with a background of some manufacturing system available to rectify the industry problems. A case study of an existing system is presented in section 3 by way of Virtual Cellular Manufacturing (VCM). In section 4 the conclusion is presented.

2. BACKGROUND

In an environment where the demand for a product can be as low as one item this tend to make the manufacturing process complex. This complexity and inefficiency comes about due to process delays; inclusive of waste within the system. Delays can be caused by waiting time (WT), set-up time (ST), machine breakdown, lack of information, workers absenteeism. An overview of the JS, GT and CM arrangement are outlined below.

2.1 JOB SHOP

To produce a large variety of products will require a number of different machinery. When similar machines are grouped together into different departments within a plant layout the arrangement is classified as a JS operation (Shafer and Charnes, 1993; Irani and Huang, 1998; Herage, 1994).

In producing a part it is sequenced through the various departments depending on the manufacturing operations required. When dissimilar parts are required to be manufacture utilizing the same machines considerable time is utilized in set-up. Further delays are encountered through material handling between departments, since different types of machines required for processing the part are in different department at a distance apart.

The JS arrangement allows manufacturers the flexibility to produce small quantities of different products that the customer requires. It also allows the manufactures the flexibility to adapt to changes in customers requirement; to quickly adjust to the manufacturing of new products and to cushion oneself when product have become obsolete.

2.2 GROUP TECHNOLOGY (GT)

An improvement of the JS operation utilizes GT. GT is simply the classification and coding (Chang et al., 1998) of similarities (Morris and Tersine, 1990; Flynn and Jacobs, 1987) between parts into families of parts. However, considerable time is required to develop. Upon classifying the families; the tools, fixtures and machinery required to produce a family of parts are grouped together into cells (Irani and Huang, 1998) within close proximity. These cells consist of functionally dissimilar machines (Shafer and Charnes, 1993; Herage, 1994; Wemmerlov and

Johnson, 1997). This arrangement facilitates a reduction in time for process planning in terms of sequence of operations.

2.3 CELLULAR MANUFACTURING (CM)

CM can be defined as an application of GT (Herage, 1994) where the families of parts that require a similar set of operations (Irani and Huang, 1998) are produced within a cell (Chang et al., 1998) utilizing all or most of the machinery in the cell. A product can be processed progressively from one workstation to another within the cell without having to wait for a batch to be completed. Cells may be dedicated to a process, a sub-component, or an entire product. Since only similar parts that require a similar set of operations are produced in the cell the set-up time for producing the product will be zero or a limited amount (Flynn and Jacobs, 1987), resulting in reduction work-in-process (WIP) inventory and throughput times, increased worker satisfaction and productivity of the shop (Morris and Tersine, 1990). However, it requires the physical reconfiguration of the machines within the JS to a cellular layout (Morris and Tersine, 1990) at considerable cost. On the other hand, when new products manufacturing are required if they do not fit into the existing cell then the whole manufacturing setup needs to be restructured. Therefore, this way of manufacturing is impractical (Flynn and Jacobs, 1987).

The distance between the machinery within the cell will be very short due to their close proximity within one another; as a result the time for material movement will be short. Due to this short distance, as one product is finish on one machine it can move onto the next machine; and do not have to wait to move in batches as is sometimes done in JS layout where the machines are placed far apart. This operation overlapping facilitates a shorter flow time of the product (Shafer and Charnes, 1993).

3. VIRTUAL CELLULAR MANUFACTURING (VCM): A NEW CONCEPT

The new concept of CM utilizes the existing JS layout (Chowdary et al., 2005). VCM utilizes the JS layout in direct conjunction with GT. When different families of parts are required to be manufactured the cells are reconfigured based on the operations requirement. It exists within the minds of the workers where the physical layouts of the machines are not rearranged but remain in their respective departments. This reformatting of cells facilitates quick changes in customer's requirement at relatively no cost to the manufacture in terms of plant layout.

With the traditional JS operation the products are not group into families, as compared with CM where the application of GT is utilized (Herage, 1994). However, with VCM since it follows on from the concept of CM, the products are grouped into families. In scheduling the families of part to be manufactured some manufacturing strategy must be followed; such as, first in – first out (FIFO), last in first out (LIFO), most expensive or most critical to operation. In this review ways in which these delays can be reduced are examined through a case study.

As the new concept was explained in the preceding lines it can be noted as a model which takes the form of the following steps:

- Jobs are grouped into families based on process similarity prior to their release, thereby reaping the setup advantages of the GT application.
- The machine selection is based on the process requirement; and the quantity of machines is based on the work load, which affects the time to complete a job.
- Family scheduling for manufacturing follows the strategies adopted by the organization which can take the form of FIFO, LILO, family size, pooling time and due date.
- Virtual Cell formation is dependent upon the scheduling of the family of parts to be manufactured and their processing requirement. Once the processing requirement on a machine within a cell is completed, and there is no other job within the family which requires the use of this machine, it is free to be utilized in the formation of another virtual cell for another family of parts. This implies that the machines are only temporally dedicated to these virtual cells.

3.1 DEMONSTRATION OF VCM THROUGH A CASE STUDY

To demonstrate the new concept of CM a case study is outline below. Jobs were taken from the company records for the last year. Therefore, it is most likely that the company will receive the same type of jobs in the following year. The jobs chosen are based on pareto analysis which is a method of classifying items according to their relative importance. The importance in this case is the Annual Revenue Value (ARV) for the company under study. This amounted to 20 jobs. The jobs arrive at the shop with a mean of 45 minutes. These jobs to be manufactured require processing in 1 to 3 departments. The sequenced of processing through their respective departments are shown in table 1.

Table 1: Process Sequence for Jobs

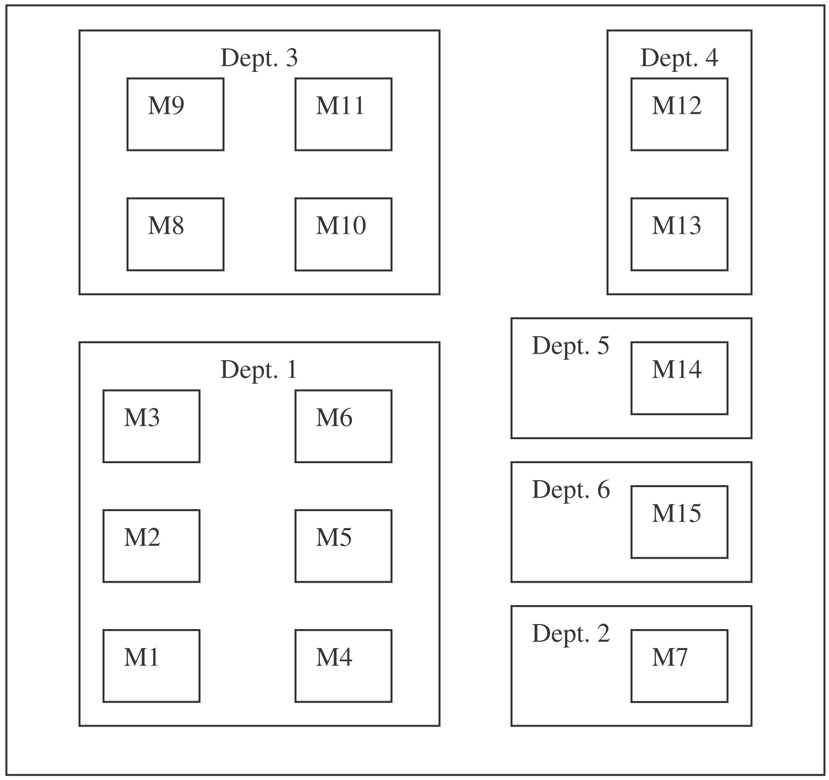
No.	Jobs Code	Job Name	Number of Operations	Departments Sequences at which Processing take place		
1	B2	Flywheel	2	1	2	
2	A1	Cylinder Head	1	1		
3	C2	Spline Gear Wheel	2	1	3	
4	B3	Forklift Assembly	2	1	2	
5	F4	Cross-slide M. Machine	2	6	3	
6	B1	Impeller	2	1	2	
7	A2	Bushing	1	1		
8	C4	Sprocket	2	1	3	
9	C1	Pump Shaft	2	1	3	
10	F3	Value Slide Gate	3	6	3	1
11	D2	Discharge Head	3	4	1	5
12	C3	Spline Shaft	2	1	3	
13	F1	Sliding Block	3	6	3	1
14	D1	Align Bush	3	4	1	5
15	E2	Jig Trolley	3	6	1	2
16	D3	Turbine Shaft	3	4	1	5
17	E1	Plates	3	6	1	2
18	F2	Pipe Clamp	3	6	3	1
19	E3	Bracket M. Support	3	6	1	2
20	E4	Shims	2	6	2	

This processing is accomplished with the aid of 15 machines arranged in 6 functional departments in the machine shop (MS), (refer table 2).

Table 2: Quantity of Machines Assigned to Departments

Departments (D)	Type of Machines in MS	Quantity	Machine Code
1	Lathe	6	M1, M2, M3, M4, M5, M6
2	Drills	1	M7
3	Milling	4	M8, M9, M10, M11
4	Boring	2	M12, M13
5	Grinding	1	M14
6	Shapers	1	M15
Total		15	

Within each functional department in the MS the quantity of machines varies. The departments are adjacent to one another, and are not duplicated. A layout of the existing machines arrangement is shown in figure 1. For the existing system the operational procedure and major issues are explained in the next section, to be followed by the new concept of CM.



Legend: Dept. – department

Figure 1: Layout of Machines in MS

3.1.1 EXISTING SYSTEM

As jobs arrive in the shop they are held in a waiting queue. The jobs are evaluated and the process operations requirements are determined. Based on these operations, the jobs are sequenced through the required departments. The scheduling of the jobs is determined on the criticality to the customer operations, otherwise on the principle of FIFO. When jobs arrive in a department after been sequenced to it, they utilized the first free machine in that department for it process operation. After which they then proceed to the next department in their sequence and again use the first free machine which is available in that department, and continues so until all the process operations are completed.

As the jobs enter a department they encounters some set-up time before processing. However, if the next job schedule to use that same machine is similar to the first no set-up is required. On the other hand if the job is dissimilar to the first one, a considerable about of time is required for set-up prior to processing. This continues for all jobs, using a range of machines within the functional departments. For the jobs considered in this study there ST for each machine operation are shown in table 3. The processing time (PT) for a job is dependant on the operation required. This time will vary based on the efficiency of the machine used and the skill of the operator. The PT for each operation of the 20 jobs considered in this study is shown in table 3.

Jobs are move manually between departments. On occasion when the jobs are heavy, they are moved with the aid of a forklift truck or over-head crane. For this study the method and the time required for movement is ignored. Also, the time taken for removing the jobs from the machines is ignored

The processing events of the existing system for the jobs are presented in table 4, with a sample description of these events at a given time until 405 minutes, in table 5. The progression of events follow the same format as described.

Table 3: Set-up and Processing Times

No.	Job Code	Job Name	D	ST	PT	D	ST	PT	D	ST	PT
1	B2	Flywheel	1	185	60	2	115	30			
2	A1	Cylinder Head	1	210	120						
3	C2	Spline Gear Wheel	1	100	240	3	305	375			
4	B3	Forklift Assembly	1	150	95	2	185	45			
5	F4	Cross-slide M. Machine	6	120	85	3	215	285			
6	B1	Impeller	1	185	120	2	85	45			
7	A2	Bushing	1	80	95						
8	C4	Sprocket	1	240	300	3	155	380			
9	C1	Pump Shaft	1	200	280	3	135	240			
10	F3	Value Slide Gate	6	340	120	3	200	120	1	120	75
11	D2	Discharge Head	4	210	420	1	135	325	5	110	285
12	C3	Spline Shaft	1	185	250	3	165	360			
13	F1	Sliding Block	6	175	120	3	115	180	1	135	90
14	D1	Align Bush	4	95	120	1	95	120	5	85	140
15	E2	Jig Trolley	6	240	120	1	120	105	2	215	110
16	D3	Turbine Shaft	4	210	305	1	95	185	5	240	320
17	E1	Plates	6	195	120	1	115	105	2	120	180
18	F2	Pipe Clamp	6	240	550	3	315	600	1	80	110
19	E3	Bracket M. Support	6	130	85	1	115	195	2	65	30
20	E4	Shims	6	205	110	2	90	30			

Legend: D – department; ST – setup time (minutes); PT – processing time (minutes)

Table 4: Processing Events of the Existing Job Shop System

JC	IA	Activity					OUT	Activity					OUT	Activity					OUT	Total			FT
		D	WT	Mc	ST	PT	IN	D	WT	Mc	ST	PT	IN	D	WT	Mc	ST	PT		WT	ST	PT	
B2	0	1	0	M1	185	60	245	2	0	M7	115	30	390						390	0	300	90	390
A1	45	1	0	M2	210	120	375						375						375	0	210	120	330
C2	90	1	0	M3	100	240	430	3	0	M8	305	375	1110						1110	0	405	615	1020
B3	135	1	0	M4	150	95	380	2	10	M7	185	45	620						620	10	335	140	485
F4	180	6	0	M15	120	85	385	3	0	M9	215	285	885						885	0	335	370	705
B1	225	1	0	M5	185	120	530	2	90	M7	85	45	750						750	90	270	165	525
A2	270	1	0	M1	80	95	445						445						445	0	80	95	175
C4	315	1	0	M6	240	300	855	3	0	M10	155	380	1390						1390	0	395	680	1075
C1	360	1	20	M4	200	280	860	3	0	M11	135	240	1235						1235	20	335	520	875
F3	405	6	0	M15	340	120	865	3	20	M9	200	120	1205	1	0	M1	120	75	1400	20	660	315	995
D2	450	4	0	M12	210	420	1080	1	0	M2	135	325	1540	5	0	M14	110	285	1935	0	455	1030	1485
C3	495	1	120	M2	185	250	1050	3	60	M8	165	360	1635						1635	180	350	610	1140
F1	540	6	305	M15	175	120	1140	3	495	M9	115	180	1930	1	0	M1	135	90	2155	800	425	390	1615
D1	585	4	0	M13	95	120	800	1	0	M3	95	120	1015	5	920	M14	85	140	2160	920	275	380	1575
E2	630	6	510	M15	240	120	1500	1	0	M3	120	105	1725	2	0	M7	215	110	2050	510	575	335	1420
D3	675	4	125	M12	210	305	1315	1	0	M4	95	185	1595	5	565	M14	240	320	2720	690	545	810	2045
E1	720	6	780	M15	195	120	1815	1	0	M2	115	105	2035	2	15	M7	120	180	2350	795	430	405	1630
F2	765	6	1050	M15	240	550	2605	3	0	M8	315	600	3520	1	0	M1	80	110	3710	1050	635	1260	2945
E3	810	6	1795	M15	130	85	2820	1	0	M3	115	195	3130	2	0	M7	65	30	3225	1795	310	310	2415
E4	855	6	1965	M15	205	110	3135	2	90	M7	90	30	3345						3345	2055	295	140	2490
																			Average	447	381	439	1266.8

Legend: JC – job code; IA – inter arrival time (minutes);
D – department; WT – waiting time (minutes); Mc – machines;
ST – setup time (minutes); PT – processing time (minutes); FT – flow time

Table 5: A Sample Processing Description of the Existing System

Time (minutes)	Event Description
0	Job B2 arrived and loaded on M1 in Dept. 1
45	Job A1 arrived and loaded on M2 in Dept. 1
90	Job C2 arrived and loaded on M3 in Dept. 1
135	Job B3 arrived and loaded on M4 in Dept. 1
180	Job F4 arrived and loaded on M15 in Dept. 6
225	Job B1 arrived and loaded on M5 in Dept. 1
245	Job B2 set-up and processing completed on M1, and move to M7 in Dept. 2
270	Job A2 arrived and loaded on M1 in Dept. 1
315	Job C4 arrived and loaded on M6 in Dept. 1
360	Job C1 arrived and waits in the queue in Dept. 1 for 20 minutes
375	Job A1 set-up and processing completed on M2, and released from the MS
380	Job B3 set-up and processing completed on M4 in Dept. 1, and move to M7 in Dept. 2; Job C1 loaded on M4 in Dept. 1
385	Job F4 set-up and processing completed on M15 in Dept. 6, and move to M9 in Dept. 3
390	Job B2 set-up and processing completed on M7, and released from the MS
405	Job F3 arrived and loaded on M15 in Dept.6

3.1.2 VCM SYSTEM

For the new concept of CM (Chowdary et al., 2005) the jobs under study are grouped into families based on process similarity and released to the shop when they are formed. However, the maximum waiting time before the family is released is 150 minutes regardless the size of the family. Table 6 shows the grouping of the jobs into families. The allocation of families and machines to cells are shown in table 7; and figure 2 shows the cells arrangement within the existing JS.

Table 6: Allocation of Jobs into Families

Family Type	Jobs in the family	Job Name	Process Sequence
A	A1	Cylinder Head	1
	A2	Bushing	1
B	B1	Impeller	1 ⇨ 2
	B2	Flywheel	1 ⇨ 2
	B3	Forklift Assembly	1 ⇨ 2
C	C1	Pump Shaft	1 ⇨ 3
	C2	Spline Gear Wheel	1 ⇨ 3
	C3	Spline Shaft	1 ⇨ 3
	C4	Sprocket	1 ⇨ 3
D	D1	Align Bush	4 ⇨ 1 ⇨ 5
	D2	Discharge Head	4 ⇨ 1 ⇨ 5
	D3	Turbine Shaft	4 ⇨ 1 ⇨ 5
E	E1	Plates	6 ⇨ 1 ⇨ 2
	E2	Jig Trolley	6 ⇨ 1 ⇨ 2
	E3	Bracket M. Support	6 ⇨ 1 ⇨ 2
	E4	Shims	6 ⇨ 2
F	F1	Sliding Block	6 ⇨ 3 ⇨ 1
	F2	Pipe Clamp	6 ⇨ 3 ⇨ 1
	F3	Value Slide Gate	6 ⇨ 3 ⇨ 1
	F4	Cross-slide M. Machine	6 ⇨ 3

Table 7: Allocation of Families and Machines to Cells

Cell (C)	Family	Job Code	Machines
C1	A B C	A1; A2 B1; B2; B3 C1; C2; C4; C4	M1; M2; M3; M7; M8; M9
C2	D	D1; D2; D3	M4; M12; M13; M14
C3	E	E1; E2; E3; E4	M5; M7; M15
C4	F	F1; F2; F3; F4	M6; M10; M11; M15

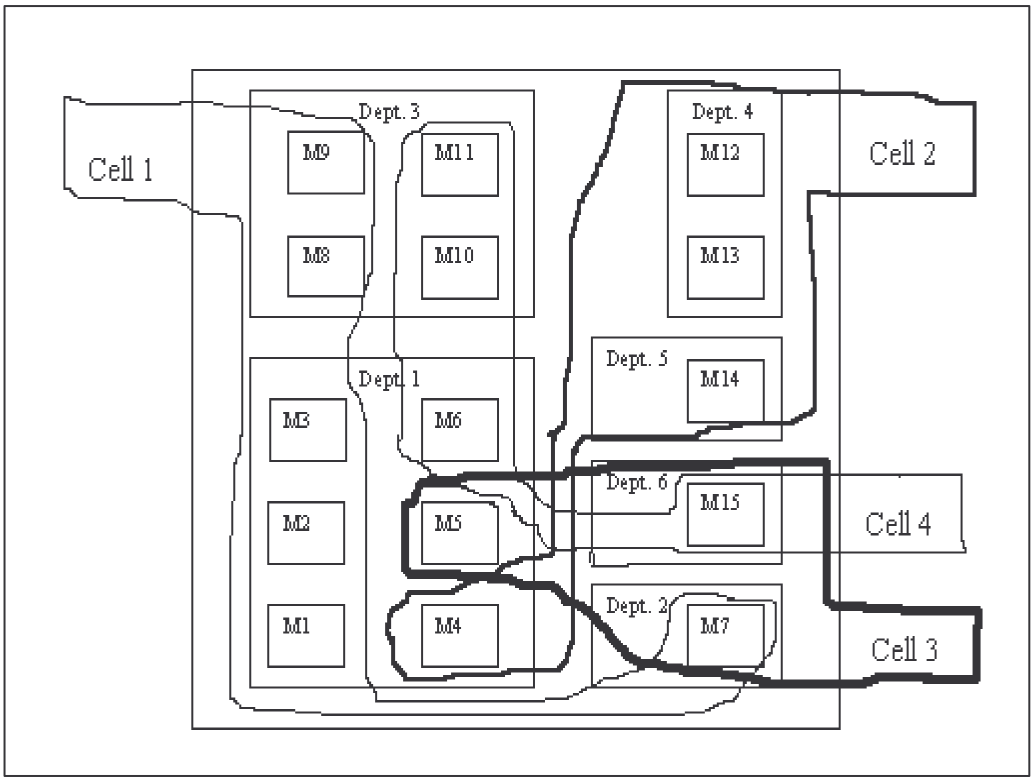


Figure 2: Cell Arrangement within the Job Shop

The processing events for the VCM system for the jobs are presented in table 8, and a sample description of these events at a given time is explained until 375 minutes, in table 9. The progression of events follow the same format as described.

Table 8: Processing Events of the VCM System

JC	IA	IN	Activity					OUT	Activity					OUT	Activity					OUT	Total			FT
			D	WT	Mc	ST	PT	IN	D	WT	Mc	ST	PT	IN	D	WT	Mc	ST	PT		WT	ST	PT	
B2	0	45	1	0	M1	185	60	290	2	0	M7	115	30	435						435	0	300	90	435
A1	45	45	1	0	M2	210	120	375						375						375	0	210	120	330
C2	90	90	1	0	M3	100	240	430	3	0	M8	305	375	1110						1110	0	405	615	1020
B3	135	135	1	155	M1	0	95	385	2	50	M7	185	45	665						665	205	185	140	530
F4	180	330	6	0	M15	120	85	535	3	0	M10	215	285	1035						1035	0	335	370	855
B1	225	225	1	160	M2	0	120	505	2	160	M7	0	45	710						710	320	0	165	485
A2	270	270	1	115	M1	0	95	480						480						480	115	0	95	210
C4	315	315	1	115	M3	0	300	730	3	0	M9	155	380	1265						1265	115	155	680	950
C1	360	360	1	145	M2	0	280	785	3	0	M9	0	240	1025						1025	145	0	520	665
F3	405	540	6	0	M15	0	120	660	3	375	M10	0	120	1155	1	145	M6		75	1375	520	0	315	970
D2	450	585	4	0	M12	210	420	1215	1	85	M4	0	325	1625	5	55	M13	0	285	1965	140	210	1030	1515
C3	495	495	1	0	M1	0	250	745	3	365	M8	0	360	1470						1470	365	0	610	975
F1	540	540	6	120	M15	0	120	780	3	0	M11	115	180	1075	1	0	M6	135	90	1300	120	250	390	760
D1	585	585	4	0	M13	95	120	800	1	0	M4	95	120	1015	5	0	M13	85	140	1240	0	275	380	655
E2	630	720	6	80	M15	240	120	1160	1	0	M5	120	105	1385	2	0	M7	215	110	1710	80	575	335	1080
D3	675	675	4	125	M13		305	1105	1	10	M4	0	185	1300	5	60	M13	0	320	1680	195	0	810	1005
E1	720	720	6	440	M15	0	120	1280	1	105	M5	0	105	1490	2	250	M7	0	180	1920	795	0	405	1200
F2	765	915	6	560	M15	240	550	2265	3	0	M10	0	600	2865	1	0	M6	0	110	2975	560	240	1260	2210
E3	810	810	6	470	M15	0	85	1365	1	125	M5	0	195	1685	2	235	M7	0	30	1950	830	0	310	1140
E4	855	855	6	510	M15	0	110	1475	2	235	M7	0	30	1740						1740	745	0	140	885
																				Average	263	157	439	893.75

Legend: JC – job code; IA – inter arrival time (minutes);
D – department; WT – waiting time (minutes); Mc – machines;
ST – setup time (minutes); PT – processing time (minutes); FT – flow time

Table 9: A Sample Processing Description of the VCM System

Time (minutes)	Event Description
0	Job B2 arrived and waits in queue
45	Job A1 arrived and forms family; Job B2 loaded on M1; Job B2 loaded on M2;
90	Job C2 arrived and loaded on M3;
135	Job B3 arrived and waits in queue;
180	Job F4 arrived and waits in queue;
225	Job B1 arrived and loaded on M2;
270	Job A2 arrived and loaded on M1;
290	Job B2 set-up and processing completed on M1, and move to M7 in Dept. 2; Job B3 leaves queue and loaded on M1;
315	Job C4 arrived and waits in queue;
360	Job C1 arrived and waits in queue;
375	Job A1 set-up and processing completed on M2, and release from the MS.

4. CONCLUSION

Research has been shown that it is possible to enhance the JS system of manufacturing by creating virtual cells (Chowdary et al., 2005). In this paper the emphasis was given to reduce waste in terms of delays in flow time (FT). FT is the total time a job takes to be completed. It is the time from being received in the machine shop for commencement of operation to the time it is completed. It includes the summation of the WT – the time the job wait in the queue before being sent to the processing machine; ST – the time it takes to set-up the job on the machine before processing can take place; and PT – the actual time taken to complete the processing; this is for all processes.

By applying the new concept of VCM for the case the average WT and ST were reduced by 41% and 59% respectively. Correspondingly, the FT for the jobs was also reduced from 1266.80 to 893.75 minutes, an improvement of 30%. The benefits form this arrangement are considerable reduction in set-up time after the first part from the family has been processed on a machine within a department. Also, the time it takes to reconfigure cells for manufacturing different families of parts will be shorter.

The economic impact of VCM is the additional information technology hardware and the personnel who will setup the database for GT and cell formation. The cost associated with this venture is considerably small in comparison to the benefit derived from the improvement in job FT. VCM gives greater flexibility at minimal cost and interruption to the manufacturers with respect to changes in customer requirements, emergent of new products and obsolete of existing products. Additional expected effects are the return business from customers who are satisfied due to shorter FT. With the reduction of ST, which is a form of waste, it creates a workforce with a culture for continuous improvement and a highly motivated staff thereby increasing productivity and profitability. It is postulated that additional research is undertaken in this area so that supplementary benefits can be derived along the value chain, by way of reduction of waste and making organization lean.

REFERENCES

Chang, T. C.; R. A. Wysk; and H. P. Wang. 1998. Computer-Aided Manufacturing. 2d. ed. Prentice Hall. p471-510.

Chowdary, B. V.; J. Slomp; and N. C. Suresh. 2005. A New Concept of Virtual Manufacturing. West Indian Journal of Engineering, 28(1): 45-60.

Flynn B. B.; and F. R. Jacobs. 1987. Applications and Implementation: An experimental comparison of cellular (Group Technology) layout with process layout. Decision Sciences 18(4): 562-581.

Herage, S.S. 1994. Group Technology and Cellular Manufacturing. IEE Transactions on Systems, Man. And Cybernetics 24(2): 203-214.

Irani, S.A.; and H. Huang. 1998. Layout Modules: A novel Extension of Hybrid Cellular Layouts. ASME International Mechanical Engineering Congress and Exposition.

Morris, S.A.; and R.J. Tersine. 1990. A Simulation Analysis of Factors Influencing The Attractiveness of Group Technology Cellular Layouts. Management Sciences 36(12): 1567-1578.

Shafer, S. M.; and J. M. Charnes. 1993. Cellular versus functional layouts under a variety of shop operating conditions. Decision Sciences 24(3):665-681.

Suresh, N. C. 1991. Partitioning Work Centers for Group Technology: Insights from an Analytical Model. Decision Sciences 22(4): 772-791.

Wemmerlov, U., and D.J. Johnson. 1997. Cellular manufacturing at 46 user plants: implementation experiences and performance improvements. International J. Prod. Res., 35(1): 29-49.