Proceedings of GLOGIFT 08
June 14-16, 2008
Stevens Institute of Technology
Hoboken, NJ, pp. 239-250

CONFIGURATION FLEXIBILITY IN VIRTUAL CELLULAR SYSTEM: A CASE STUDY

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ABSTRACT

In today's competitive world, producers of goods are under constant and intense pressure to quickly and continuously improve their operations by enhancing productivity, quality and responsiveness. Virtual cellular manufacturing (VCM) is being used as a philosophy with broad applicability in manufacturing sector to reduce movement of jobs, set-up times and lead times. As a result, there is a surge of interest in this area by the industry.

The paper provides an integrated framework for the development of solution methods and heuristics by incorporating various flexibilities in the formation of virtual cells within job shop setup. Through an extensive review of literature in traditional manufacturing areas, a new approach for cell formation that integrates machine grouping and layout design is followed with flexibility as a main focus in this paper. The proposed framework will try to address several performance evaluation issues such as system utilization, work-in-process inventory and related flexibilities.

Keywords: *Virtual manufacturing cells, regrouping, job shop operations, flexibility, system utilization.*

Introduction

The manufacturing industry produces a large variety of products in order to satisfy the diverse needs of markets. This is due to the dynamic environment in which we live; and informed customers who desire goods with closer tolerances (Degarmo, Black and Kohser, 1997) and demand additional features (Evans and Lindsay, 2005). Hence, customer satisfaction (Mason-Jones, Naylor and Towill, 2000) is of utmost importance. As a result manufacturering operations must be flexible to accommodate the varying needs of customers. Flexible operations are responsive; they are able to react when customers make unexpected demands (Szwejczewski and Cousens, 2007). It has become one of the most sought after properties in modern manufacturing systems (Shewchuk, 1999) in order to handle uncertainties and variations (Ramasesh and Jayakumar 1991) in both internal and external environment.

Customers require goods and services which must be easily available with short lead time and of a high quality at very competitive prices. This is evident within the manufacturing industry in Trinidad and Tobago (TT) as field trips were undertaken and discussions held with members of Trinidad and Tobago Manufacturers Association. The product variety which is produced in the manufacturing industries within TT is accomplished through Job Shop (JS), Flow Shop, Project and Continuous Processes. In an environment where the customer demands are of small quantities

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from a large variety and in most cases one of a kind (Degarmo, Black and Kohser, 1997), then the JS manufacturing operation becomes critical.

In order for manufactures to survive in the turbulent environment in which we operate, they must be competitive in all aspects. Getting the right product, at the right price, at the right time to the consumer is the key to survival (Mason-Jones, Naylor and Towill, 2000). Efficient utilization of workers, materials and machines (Degarmo, Black and Kohser, 1997) is critical for success of any organization. As a result, the elimination of waste (Evans and Lindsay, 2005) is a major strategy being pursued by manufactures globally. Ohno (1998) postulated that waste is what drives up cost. The elimination of these wastes is being undertaken by a culture of continuous improvement – kaizen, kanban – "pull" production, mistake-proofing – poka-yoke, just in time, value stream mapping, cellular manufacturing (CM) and virtual cellular manufacturing (VCM). Additionally, to bring about competitive advantage flexibility together with cost, quality and time (Szwejczewski and Cousens, 2007); is now a strategic objective being pursued by international manufacturers. Therefore, for longevity and profitability of the local manufactures, more so for the JS manufactures, this practice of flexibility must be incorporated within their respective plants. It must be embedded in their business plan, and diligently followed. VCM as outline by Chowdary et al. (2005) and Slomp et al. (2005) demonstrated this flexibility and now in this paper it will be tested through a case study.

Therefore, the objective of this paper is a comparison of the JS performance with the traditional cellular manufacturing (CM) and the new concept of VCM. This will be evaluated against shop performance measures, such as waiting time (WT), set-up time (ST) and flow time (FT). This reconfiguration for flexibility will be accomplished during the shortest time and at the lowest cost, by varying the methods of production with a minimum interruption to the manufacturer.

In order to meet the objective of this paper the remainder of this paper is arranged as follows: section 2 introduces VCM. A case which widely represents the JS manufacturing sector in TT is identified in section 3 and section 4 present strategies to alleviate the problems identified. A discussion follows in section 5 and the paper ends with a conclusion in section 6.

Virtual Cellular Manufacturing

VCM follows on from CM; hence, it utilizes the principles and philosophy of group technology (GT) (Chang et al., 1998) for the formation of families of parts. In the formation of these families there should be the avoidance to the addition of new machinery, while at the same time the existing machinery within the JS should be efficiently utilized. This affords us to minimize job ST through pooling synergy of machines (Suresh and Meredith, 1994). Implementation of a VCM arrangement maintains the physical JS layout as exist at the company. There is no reconfiguration of the machine and departments; they remain in the same physical location (Chowdary et al., 2005). That is, the machine within the existing department is retained.

Based on the processing requirements for the family of parts the appropriate machinery will be identified for the virtual cells. Remember these cells configuration will only be in the minds of the workers. The machines are only temporarily dedicated to the cells. Once the part family processing has been completed, the cells are disbanded and are free to associate themselves with other cells for the processing of other families. This reformatting of cells facilitates quick changes in customer's requirement at relatively no cost to the manufacture in terms of plant layout, thus affording them the benefits of volume and mix flexibility (Szwejczewski and Cousens, 2007).

Case Study

Background to Case

In order to facilitate the identification of common problems and a basis for the generation of common solutions interviews and discussions were held; and observations were made to the actual way in which firms operated in TT. It was noticed that wastage was taking place on the shop floor from various processes. We can conclude that the majority of customers are not satisfied due to delays; to which the customers are asked to pay more prices. This conclusion is further reinforced with over 20 years of personal experience working in a JS environment at a state company by the first author. However, based on an extensive literature search and field visits factors which contribute to a number of difficulties inclusive of delays are categorized as management and operational levels issues and are listed below.

Management Issues

- No documented or adopted policy that is strictly followed in terms of job scheduling (Flynn and Jacobs, 1987).
- No planned replacement and upgrades of machinery (Shafer and Charnes, 1993).
- No scientific maintenance programs for plant and machinery resulting in equipment breakdown and unavailability, which leads to additional waiting time (Conner, 2001).
- Lack of training pertaining to new operational techniques and upgrade of skills (Conner, 2001).
- No planned succession program for continuity of effective and efficient operations.
- Low employee moral due to lack of motivation and compensation (Shafer and Charnes, 1993).

Operational Issues

- Due to implementation of the non-scientific methods of material handling and the arrangement of facilities within JS, delays in movement of materials occur.
- Lack of detailed information on the job sheet, therefore operators often seek clarification; resulting in delays.
- The amount of time taken to set-up jobs is resulting in further job delays and leads to high work-in-process inventory.

All these delays lead to a high flow time and low system utilization. An assessment of the above issues within the local manufacturing industry shows that there is wastage in resources, inclusive of time. All of the above contribute to customer dissatisfaction – when they have to suspend their individual operations. This result in difficulties to their own consumers and intricacy in retain them. Additionally, there is lost of revenue and profit to all. Hence, to mitigate these issues an alternative mode of JS operation like VCM which facilitates configuration flexibility is taken up in this paper for investigation purposes. Recognizing across the manufacturing industry that most of the customer's order delays occurred at the operational level, it will be a good starting point to reduce such delays at this level, in order to improve the shop performance through machine scheduling flexibility.

Shop Layout

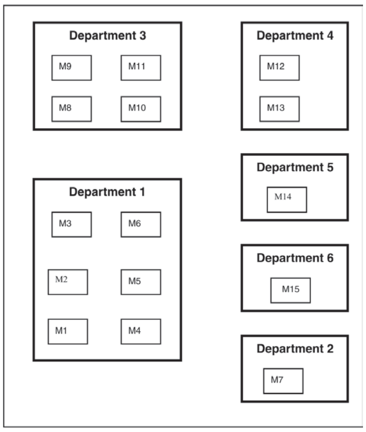
The manufacturing operation within the existing JS is accomplished by 15 machines arranged in six (6) functional departments. Table 1 identifies the quantity of machines to each department.

Table 1: Machine Allocation to Departments

Departments (D)	Machine Type		Machine Code used in the Study
	Name	Number	
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	

Legend: M1, M2… M15 – Machine 1, Machine 2… Machine 15

A schematic layout of the arrangement of the existing machines is shown in Figure 1.



Legend: Departments 1, 2 …6, and M1, M2… M15, corresponds to Table 1.

Figure 1: Job Shop Layout

Method of Operation

When a job arrives in the JS it is held in a waiting queue. After which the jobs are sequenced through the required departments based on the operational requirements. The scheduling of the jobs is determined by the job criticality; otherwise on the basis of first in first out (FIFO).

After the jobs have been sequenced, they utilize the first free machine in that department for its operation. If a second operation is required then it will proceed to the next department as per the sequence and again use the first free machine which is available in that department and continues so until all the operations are completed. When a second operation is required and a machine is available, the jobs are scheduled based on the job which was schedule to the first operation first, and not necessarily the job which arrive to JS first. However, this does not apply if a latter schedule job can be completed in its second processing department before the earlier job arrives in that department.

Some ST is encountered before processing, as jobs enter a department. However, if the next job schedule to use that same machine is similar to the first no major setup is required. On the other hand if the job is dissimilar to the first one, a major setup is required prior to processing. This continues for all jobs, using a range of machines within the functional departments. For the jobs considered in this paper job setup times and processing times are given in Table 2. In this paper job handling time is ignored.

Data Collection and Analysis

From the company records we were able to obtain the job request that was made by clients over the last 12 months. A 12-month period was chosen because it is most likely that the company will receive similar type of jobs in the following 12 month period. This data was filtered to represent the jobs that were specifically assigned to the JS. The number of jobs that were assigned to the JS was 756. Based on the Annual Revenue Value (ARV) and pareto analysis the jobs were rank. 25 jobs are chosen for evaluation purpose that contributed more than $50,000 revenue. The company management emphasized that efforts should be concentrated where the most financial benefit can be derived. As a result, these are the jobs which will form the basis of this paper.

The 25 jobs to be manufactured require processing in 1 to 3 departments. The sequenced of processing through their respective departments are shown in Table 2. For example, for job 5415 the number of processing departments is 3 and the sequence of departments at which processing takes place is from 1-3-5. For the 25 jobs selected the ST and PT are given in Table 2. It was assumed that the JS operated for 48 weeks at 6 days per week and 8 hours per day. The resulting calculation gives a job arrival time of approximately three (3) hours. The 25 jobs will be rearranged based on their actual arrival order for scheduling within the JS, as shown in Table 2.

For the existing system the processing events is presented in Table 2 for the 25 jobs under study. A sample description of these events is at row 3 and column 14 for Job 5422, the cell represent that at 14.75 hours Job 5422 set-up and processing is completed on M7 in department 2, and move to department 6 and loaded on M15; and at row 6 and column 1 Job 5631 is loaded on M7 in department 2. The progression of events follow the same format as described.

Table 2: Processing Events of the Existing JS System

Jobs	IAT	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	
5415	0	1	0	M1	3.75	16	19.75	3	0	M9	3.25	7	30.00	5	0	M14	1.5	8	39.50	0	9	31	39.50
5422	3	1	0	M2	3	4.5	10.50	2	0	M7	1.5	2.75	14.75	6	0	M15	1.5	3.25	19.50	0	6	11	16.50
5483	6	1	0	M3	2.5	7.5	16.00	3	0	M8	2.5	4	22.50	6	0	M15	3	4.5	30.00	0	8	16	24.00
5484	9	1	0	M4	7	12	28.00	3	0	M10	3	16	47.00	5	0	M14	7	12	66.00	0	17	40	57.00
5631	12	2	2.75	M7	3	6	23.75	4	0	M12	2.5	6	32.25	5	0	M14	3	6	41.25	3	9	18	29.25
5661	15	1	0	M2	4	6	25.00	3	0	M8	3.75	4.75	33.50	4	0	M12	2.75	4	40.25	0	11	15	25.25
5685	18	1	0	M3	4.5	20	42.50	3	0	M9	2.5	8	53.00	4	0	M12	3.5	6	62.50	0	11	34	44.50
5703	21	1	0	M1	3	8	32.00	2	0	M7	2	6	40.00	4	0	M13	4	6	50.00	0	9	20	29.00
5760	24	1	0	M5	2.75	4	30.75	2	9.25	M7	3	2.5	45.50	6	0	M15	3	4.5	53.00	9	9	11	29.00
5841	27	1	0	M2	3	6	36.00	3	0	M8	2.25	4.75	43.00						43.00	0	5	11	16.00
5986	30	1	0	M1	4	24	58.00	2	0	M7	3	11	72.00	6	0	M15	2	6	80.00	0	9	41	50.00
6139	33	1	0	M4	3.25	4.5	40.75	2	0	M7	3.5	4.25	48.50	6	4.5	M15	2.5	3	58.50	5	9	12	25.50
6186	36	1	0	M2	2.5	16	54.50	3	0	M8	1	8	63.50	5	0	M14	2	8	73.50	0	6	32	37.50
6191	39	1	0	M5	5	20	64.00	3	0	M8	1	8	73.00						73.00	0	6	28	34.00
6211	42	1	0	M4	5	24	71.00	3	0	M9	3	8.5	82.50	4	0	M12	4.5	7	94.00	0	13	40	52.00
6212	45	1	0	M3	4.5	20	69.50	3	0	M10	2.5	8	80.00	4	0	M13	3.5	6	89.50	0	11	34	44.50
6265	48	1	0	M6	1.75	4	53.75	5	0	M14	1	4	58.75						58.75	0	3	8	10.75
6271	51	4	0	M13	3.5	8	62.50	5	11	M14	3	6	82.50						82.50	11	7	14	31.50
6313	54	1	0	M6	6.5	12.5	73.00	5	9.5	M14	0.5	16	99.00						99.00	10	7	29	45.00

Legend: IAT - inter-arrival time; D –department's numbers; WT - waiting time; Mc – machine; ST - set-up time; PT - processing time

6392	57	1	0	M2	2.5	16	75.50	6	4.5	M15	1.5	4.5	86.00						86.00	5	4	21	29.00
6396	60	4	2.5	M12	2	7	71.50	6	14.5	M15	1.25	3	90.25						90.25	17	3	10	30.25
6444	63	1	O	M1	2.5	5	70.50	2	0	M7	3.75	6.25	80.50	6	9.75	M15	2.5	5	97.75	10	9	16	34.75
6526	66	2	14.5	M7	4	16	100.50	6	0	M15	6	20	126.50						126.50	15	10	36	60.50
6568	69	1	0	M2	3.25	4.75	77.00	4	0	M12	3.75	5	85.75	5	13.25	M14	1.75	2.25	103.00	13	9	12	34.00
6584	72	1	0	M1	4	8	84.00	3	0	M8	6	6	96.00						96.00	0	10	14	24.00
																		Average		4	8	22	34.13

For the 25 Jobs that were processed through the existing JS system the result are summaries as shown in Table 3. The average times in hours are:

Table 3 Summary of Results for the Existing JS System

Description	Average Time (hours)
Wait Time	4
Set-up Time	8
Processing Time	22
Flow Time	34.13

In order to improve the existing system, two cellular strategies will be adapted and analyzed for the data in the next section.

Adaptation of Strategies

In order to improve customer satisfaction with those clients who interact with the company and to achieve the objectives previously set, the company's operational efficiency must increase. This will be accomplished by the adoption of new strategies. These strategies will be explained and then evaluated.

Cellular Manufacturing

CM involves the processing of jobs within a cell. As a result the existing plant layout at the company which is a JS layout will have to be reconfigured to a cellular layout. The individual jobs will be classified based on the principles and philosophy of GT. The jobs will be classified into families based on similarities in processing requirement. The machines required to accomplish the processing requirement will be determined. Hence, the requirement for the cell configuration will be established. Within the physical layout the various cells location will be identified; and the previously established cell configuration will be installed. That is, the existing JS layout will be reconfigured to accommodate the cells. With CM the machines are permanently dedicated to the assigned cell. Based on the scheduling policy the various jobs will be scheduled to the appropriate cells for manufacturing based on the concept of processing families of parts. The scheduling policy adopted is FIFO; therefore, this will be used in this paper.

In analyzing the data the 25 jobs were grouped into four families and were assigned into four cells. For the families of parts the machines have been identified based on the departments at which processing takes place. It will be considered that all machines within the same category have the same capability. This will avoid variation in cycle time and prevent the desire to duplicate machines of the same category of various capabilities within the same cell.

Based on the configuration developed it is recognized that there is a need for additional machines. However, there will be excess machines within some department. In order to create the cells with the appropriate machines, where additional machines are required, they will be introduced. By following this methodology the four families and machines were allocated to four cells as shown in Table 4.

Table 4: Allocation of Families and Machines to Cells

Family	Cell	Machines
A	Cell–A	M1; M7; M15
B	Cell–B	M2; M8; M12
C	Cell–C	M3; M9; M14
D	Cell–D	M4; M16; M10; M13; M17; M18

Legend: M1, M2… M15: Existing Machines
M16, M17, M18: New Machines

The additional machines which will be needed to facilitate the formation of Cell–D are: one drill press, one grinding machine and one shaping machine. These additional machines are referred as M16; M17 and M18. The unutilized machines in the cell formation are: two lathes (M5 and M6) and one milling machine (M11). These machines can be used for other purposes. The cellular layout with the respective machines assigned to cells is shown in Figure 2.

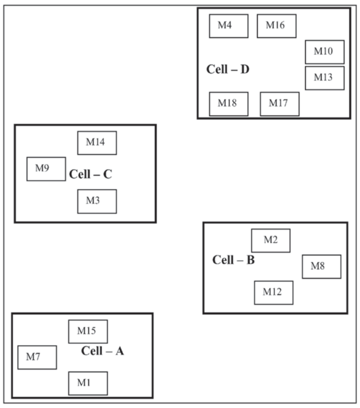


Figure 2: Machine Allocation in Cellular Layout

Using the data for ST and PT and with an inter-arrival time for the jobs of three (3) hours these 25 jobs will be schedule through the cellular layout based on the strategy adapted in the preceding section and the result are observed. Again, this scheduling will be based on the actual arrival pattern of the jobs. It should be recalled that ST only occurs the very first time the part family is processed on the machine within a cell. These results for the processing events for the CM system for the jobs are shown in Table 5. A sample description of these events is at row 2 and column 8 for Job 5415, the cell represent that at 19.75 hours Job 5415 set-up and processing is completed on M3 in Cell-C, and move to M9 in Cell-C; and at row 5 and column 1 Job 5484 is loaded on M3 in Cell-C. The progression of events follow the same format as described.

Table 5: Processing Events of the CM System

Job	Cell	IAT					OUT					OUT					OUT	Total			FT
			WT	Mc	ST	PT	IN	WT	Mc	ST	PT	IN	WT	Mc	ST	PT		WT	ST	PT	
5415	C	0	0	M3	3.75	16	19.75	0	M9	3.25	7	30.00	0	M14	1.5	8	39.50	0	9	31	39.50
5422	A	3	0	M1	3	4.5	10.50	0	M7	1.5	2.75	14.75	0	M15	1.5	3.25	19.50	0	6	11	16.50
5483	D	6	0	M4	2.5	7.5	16.00	0	M10	2.5	4	22.50	0	M18	3	4.5	30.00	0	8	16	24.00
5484	C	9	10.75	M3		12	31.75	0	M9		16	47.75	0	M14		12	59.75	11	0	40	50.75
5631	D	12	0	M16	3	6	21.00	0	M13	2.5	6	29.50	0	M17	3	6	38.50	0	9	18	26.50
5661	B	15	0	M2	4	6	25.00	0	M8	3.75	4.75	33.50	0	M12	2.75	4	40.25	0	11	15	25.25

5685	B	18	7	M2	4.5	20	49.50	0	M8	2.5	8	60.00	0	M12	3.5	6	69.50	7	11	34	51.50
5703	D	21	0	M4		8	29.00	0	M16		6	35.00	0	M13		6	41.00	0	0	20	20.00
5760	A	24	0	M1		4	28.00	0	M7		2.5	30.50	0	M15		4.5	35.00	0	0	11	11.00
5841	B	27	22.5	M2	3	6	58.50	1.5	M8	2.25	4.75	67.00					67.00	24	5	11	40.00
5986	A	30	0	M1		24	54.00	0	M7		11	65.00	0	M15		6	71.00	0	0	41	41.00
6139	A	33	21	M1		4.5	58.50	6.5	M7		4.25	69.25	1.75	M15		3	74.00	29	0	12	41.00
6186	C	36	0	M3		16	52.00	0	M9		8	60.00	0	M14		8	68.00	0	0	32	32.00
6191	B	39	19.5	M2	5	20	83.50	0	M8	1	8	92.50					92.50	20	6	28	53.50
6211	B	42	41.5	M2	5	24	112.50	0	M8	3	8.5	124.00	0	M12	4.5	7	135.50	42	13	40	93.50
6212	B	45	67.5	M2	4.5	20	137.00	0	M8	3.25	8	148.25	0	M12	3.5	6	157.75	68	11	34	112.75
6265	C	48	4	M3		4	56.00	12	M14		4	72.00					72.00	16	0	8	24.00
6271	D	51	0	M13		8	59.00	0	M17		6	65.00					65.00	0	0	14	14.00
6313	C	54	2	M3		12.5	68.50	3.5	M14		16	88.00					88.00	6	0	29	34.00
6392	A	57	1.5	M1		16	74.50	0	M15		4.5	79.00					79.00	2	0	21	22.00
6396	D	60	0	M13		7	67.00	0	M18		3	70.00					70.00	0	0	10	10.00
6444	A	63	11.5	M1		5	79.50	0	M7		6.25	85.75	0	M15		5	90.75	12	0	16	27.75
6526	A	66	14	M7		16	95.50	0	M15		20	115.50					115.50	14	0	36	49.50
6568	D	69	0	M4		4.75	73.75	0	M13		5	78.75	0	M17		2.25	81.00	0	0	12	12.00
6584	B	72	65	M2	4	8	149.00	0	M8	6	6	161.00					161.00	65	10	14	89.00
																Average		13	4	22	38.44

Legend: IAT - inter-arrival time; WT – waiting time; Mc – machine; ST - set-up time; PT– processing time

Virtual Cellular Manufacturing

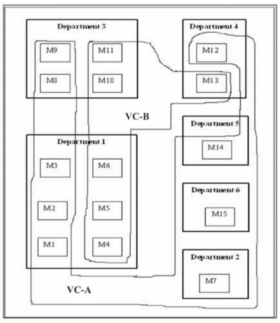
The utilization of the concept of VCM affords us with a number of strategies for the formation of families for the various Jobs to be process. These strategies can be based on: number of families; pooling time of families; size of families; similarities in processing requirement; due date and family releasing mechanism. For this paper, the strategy adopted for the formation of families is based on similarities in processing requirement.

Since VCM follows CM, the family formation used for CM will initially be the same for VCM. However, as it pertains to pooling synergy of machines, the 25 Jobs were classified only into two families of parts, as our strategy; compared to CM where four families have been created. These two families resulted from the merging of the families of parts. Family types C and D were merged with A; and family type B remained the same. This resulted in two families and two cells. The reduction in families with VCM affords us to minimize job ST. Also, the configuration risk will be reduced due to minimum disruption to the JS operations. By following this methodology and with the emphasis on maximum utilization of machinery, these families will be assigned to virtual cells; as shown in Table 6.

Table 6: Allocation of Families and Machines to Virtual Cells

Family	Virtual Cell	Machines
A	VC-A	M1; M2; M3; M7; M8; M9; M12; M14; M15
B	VC-B	M4; M5; M6; M10; M11; M13

The layout with the respective machines assigned to virtual cells is shown in Figure 3.



Legend: Departments 1, 2…6, and M1, M2M15, corresponds to Table 4.

Figure 3: Virtual Cellular Layout

Families will be released to the JS virtual cells for processing when they are formed. That is, when jobs arrive into the shop they are evaluated to determine which family they belong to, and are assigned to their respective family queue. The minimum size of the family considered for this study is two jobs. The company consented for the size of the family to have a minimum of two jobs. However, the maximum job waiting time for the formation of a family from when the job first arrives in the shop until it is released to the JS is 9 hours.

The initial order of arrival will be used together with the ST and PT for the manufacturing of jobs. As it pertain to the addition of jobs to formed family – if a family has been schedule and is processing within the virtual cells, and another family part arrives in the shop, it joins the family for processing to save ST. With respect to re-routing – if a latter job can be completed in the second process before the earlier job arrives to the workstation within the cell, the latter job can be process.

For the VCM system the processing events is presented in Table 7 for the 25 jobs. A sample description of these events is at row 3 and column 9 for Job 5422, the cell represent that at 10.5 hours Job 5422 set-up and processing is completed on M2 in VC-A, and move to M7 in VC-A; and at row 5 and column 1 Job 5484 is loaded on M2 in VC-A. The progression of events follow the same format as described.

Table 7: Processing Events of the VCM System

Job	Cell	IAT	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	
5415	VC-A	0	1	3	M1	3.75	16	22.75	3	0	M8	3.25	7	33.00	5	0	M14	1.5	8	42.50	3	9	31	42.50
5422	VC-A	3	1	0	M2	3	4.5	10.50	2	0	M7	1.5	2.75	14.75	6	0	M15	1.5	3.25	19.50	0	6	11	16.50
5483	VC-A	6	1	0	M3	2.5	7.5	16.00	3	0	M9	2.5	4	22.50	6	0	M15	0	4.5	27.00	0	5	16	21.00
5484	VC-A	9	1	1.5	M2	0	12	22.50	3	0	M9	0	16	38.50	5	4	M14	0	12	54.50	6	0	40	45.50
5631	VC-A	12	2	2.75	M7	0	6	20.75	4	0	M12	2.5	6	29.25	5	25.25	M14	0	6	60.50	28	3	18	48.50
5661	VC-B	15	1	3	M4	4	6	28.00	3	0	M10	3.75	4.75	36.50	4	0	M13	2.75	4	43.25	3	11	15	28.25
5685	VC-B	18	1	0	M5	4.5	20	42.50	3	0	M10		8	50.50	4		M13	0	6	56.50	0	5	34	38.50
5703	VC-A	21	1	0	M3		8	29.00	2	0	M7		6	35.00	4	0	M12	0	6	41.00	0	0	20	20.00
5760	VC-A	24	1	0	M1		4	28.00	2	7	M7	0	2.5	37.50	6	0	M15	0	4.5	42.00	7	0	11	18.00
5841	VC-B	27	1	0	M6	3	6	36.00	3	0	M11	2.25	4.75	43.00						43.00	0	5	11	16.00
5986	VC-A	30	1	0	M1	0	24	54.00	2	0	M7	0	11	65.00	6	0	M15	0	6	71.00	0	0	41	41.00
6139	VC-A	33	1	0	M2	0	4.5	37.50	2	0	M7	0	4.25	41.75	6	0	M15	0	3	44.75	0	0	12	11.75
6186	VC-A	36	1	0	M3	0	16	52.00	3	0	M8		8	60.00	5	0.5	M14	0	8	68.50	1	0	32	32.50
6191	VC-B	39	1	0	M4	0	20	59.00	3	0	M10	0	8	67.00						67.00	0	0	28	28.00

6211	VC-B	42	1	0	M6	0	24	66.00	3	0	M11		8.5	74.50	4	0	M13	0	7	81.50	0	0	40	39.50
6212	VC-B	45	1	0	M5	0	20	65.00	3	2	M10		8	75.00	4	6.5	M13	0	6	87.50	9	0	34	42.50
6265	VC-A	48	1	0	M1	0	4	52.00	5	0	M14	0	4	56.00						56.00	0	0	8	8.00
6271	VC-A	51	4	0	M12	0	8	59.00	5	3	M14	0	6	68.00						68.00	3	0	14	17.00
6313	VC-A	54	1	0	M1	0	12.5	66.50	5	1.5	M14	0	16	84.00						84.00	2	0	29	30.00
6392	VC-A	57	1	0	M1	0	16	73.00	6	0	M15	0	4.5	77.50						77.50	0	0	21	20.50
6396	VC-A	60	4	0	M12	0	7	67.00	6	0	M15	0	3	70.00						70.00	0	0	10	10.00
6444	VC-A	63	1	0	M2	0	5	68.00	2	0	M7	0	6.25	74.25	6	3.25	M15	0	5	82.50	3	0	16	19.50
6526	VC-A	66	2	8.25	M7	0	16	90.25	6	0	M15	0	20	110.25						110.25	8	0	36	44.25
6568	VC-A	69	1	0	M2	0	4.75	73.75	4	0	M12	0	5	78.75	5	5.25	M14	0	2.25	86.25	5	0	12	17.25
6584	VC-B	72	1		M4		8	80.00	3		M10		6	86.00						86.00	0	0	14	14.00
																			Average		3	2	22	26.82

Discussion

A summary of the results derived from an assessment of the strategies generated; together with the present strategy being followed by the company is shown in Chart 1. This summary is based on the following shop performance measures: WT, ST, PT and FT. Corresponding to Chart 1, the average WT for the 25 Jobs for the existing strategy is 4 hours; whereas for the proposed strategies of CM is 13 hours and VCM 3 hours respectively.

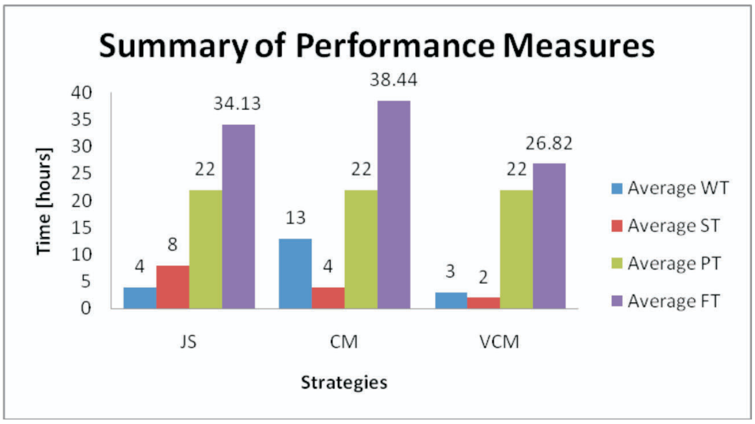


Chart 1: Summary of Performance Measures

A comparison of the above data is shown in a tabulated format in Table 8.

Table 8: Comparison of Performance Measures in Terms of Percentage

Items	Shop Performance Measures	Strategies		
		CM vs. JS	VCM vs. JS	VCM vs. CM
1	Waiting Time	225% increase	25% decrease	77% decrease
2	Set-up Time	50% decrease	75% decrease	50% decrease
3	Processing Time	same	same	same
4	Flow Time	12.63% increase	21.42% decrease	30.23% decrease

The ST showed a decrease of 50% with CM when compared with the JS. However, the WT increased by 225%. This is a result of the permanent machine dedication with CM (Irani and Huang 1998). The effect of this resulted in an increase of the FT by 12.63% with the CM strategy. Furthermore, with the CM strategy as described previously, there are problems with its implementation. Foremost is a considerable amount of capital must be invested. This will be used for shop reconfiguration and the purchase of additional machines. Every time the products mix changes the CM layout will have to be reconfigured. Therefore, this type of manufacturing system is impractical (Flynn and Jacobs 1987).

The VCM system showed a decrease with the ST and FT of 75% and 21.42% respectively, when compared with JS. This decrease was greater than the CM. With VCM there is no reconfiguration of the JS. The existing JS layout remains the same when implementation of VCM occurs. No new machinery is purchase and added to the current shop. Comparing the VCM system with the CM system, as the data shows, also resulted in decreases in WT by 77%, ST by 50% and FT by 30.23%. These results verify that between the VCM and the CM layouts, the VCM layout is superior. As a result the existing strategy must clearly be changed due to customer dissatisfaction.

Conclusion

Due to delays in the delivery of customer's orders by JS manufacturers the customers are dissatisfied. This is felt in terms of inconvenience to their respective customers and in their balance sheet in terms of profit. The driver of the economy of TT is the energy sector. They are the major revenue earners of the JS manufacturers. As a result, the JS manufacturers must change their existing strategy and adopt an alternative mode of JS operation; such as VCM for their survival.

As a study, a JS setup was analyzed and two cellular strategies were adapted. The results were compared. The comparison revealed superior results for both the CM and VCM strategies in terms of ST when compared against the existing JS strategy. However, in terms of FT, CM strategy was less attractive than the existing JS strategy; while the VCM strategy was very attractive. Furthermore, the results also revealed that the VCM strategy was better than the CM strategy.

Successfully implementation of VCM to an existing JS layout brings benefits such as – reduction in WT, ST and FT. The effects of this reduction results in a drastic decline in WIP and affords the availability of the system. That is, increase in system utilization. Furthermore, the existing JS layout is retained. There is no capital investment for reconfiguration of the shop as compared to CM. VCM is flexible in assigning jobs and the virtual cells can be rearranged very rapidly. Additionally, this system affords the quick adaptation to changes in both product mix and volume.

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