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A Simulation Based Study to Enhance Productivity by Forming Virtual Cells in a Job Shop

KEYWORDS

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ABSTRACT *In this competitive environment, the existing layout configurations in industries struggle to meet the fluctuations in demand and hence there is a need for implementing suitable layouts (Flexible and Reconfigurable) for appropriate. The flexibility and reconfigurability can overcome the cost incurred in redesigning the layout for changes in production requirements and can meet the demand fluctuations. When the demand of part mix varies in a dynamic manner, the existing layout's underperform where virtual cellular layouts can perform better. So in my work, with addition of part mix variations, different layouts are studied and simulated using Witness 2006. The performance measures are compared and a suitable layout is suggested to accommodate fluctuations in demand and mix*

Introduction:
All World class companies are under pressure, without exemption, to constantly improve upon, in manufacturing their products in shortest time, with a focus on customer satisfaction. Obviously they look for better operational results by reducing lead time, cost, update technology, and host other effective measures to ensure their leadership in the market. In order to respond to dynamic changes in the market, companies aim to improve their flexibility by applying flexible manufacturing systems (FMS), Cellular manufacturing (CM) and group technology (GT) principles.

Cellular manufacturing (CM) has been one of the manufacturing systems to meet the above challenges for a long time. It assumes physical groupings of machines, each grouping or cell being dedicated to the manufacturing of a product family. The similarities in manufacturing requirements for members of a product family lead to reduced set-ups, less material handling, and many more advantages.

The conventional definition of manufacturing cell is restricted. The requirements of parts within the family must go from raw material to finished within a single cell makes the manufacturing cells design a very complex problem. The presence of alternative routing, duplication of resources, and outsourcing may not eliminate the problem of intercell flows. So, there is no need to relax the restriction by allowing the jobs to move between cells.

Virtual cells allow the time sharing of machines among different cells producing different part families, but having overlapping resource requirements. Thus, the restriction of confining a part to only one cell is relaxed. Machines in the functional layout can be used to a family without physically disturbing those shared machines among two or more cells, by simply assigning tools and fixtures to a machine, it can be used to different part families in production. Thus, Machine and routing flexibilities of the job shop can be maintained in the cellular manufacturing system.

Virtual Manufacturing cells:
The virtual manufacturing cell concept was first developed by the National Bureau of Standards to address specific control problems encountered in the design phase of continuous flow manufacturing of small batches of machines parts. A virtual cell was defined "as a logical grouping of products and resources within a controller" It allows time sharing of workstations with other cells by virtue of overlapping resource requirements.

Virtual cellular manufacturing has been proposed to be an alternative to CM, for functional layout settings where a conversion to CM is not feasible from a technical or financial perspective. Instead of physical re-allocation of machines as in CM, VCM proposes to reduce set-up times by grouping similar jobs in production planning and control. Hence the through put time of the jobs in the shop floor may be improved.

VCM achieves many of the benefits associated with CM, while retaining and building on the routing flexibility on the functional layout, ie., the possibility to choose from the alternative machines to execute an operation.

In this paper, we have considered the investments in routing flexibility such as machine relocation, tools, fixtures and operation sequence of parts. Often there are operations in the cells, which contribute more toward intercellular flow to intracellular flows. So these types of operations needs to be identified and shifted to a cell in which they contribute maximum towards the intracellular flow, provided they do not increase the overall processing cost for the whole manufacturing system.

The work takes the utilization of machines with in the cell as an evaluation criterion for determining the fairness of the various solutions generated. The methodology cross checks the utilization criterion by evaluating the material handing cost and time. These measures judge the operations contribution towards intracellular flows. The virtual cellular system proposed here is a new cell design concept which enables a job shop to limit machines grouping and machines duplication by having a semi functional layout and allowing some intercellular flows.

The virtual cells are created periodically depending on changes in demand volumes and mix, as new jobs accumulate during a planning period.

Once a job order arrives, a Virtual cellular controller will

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take over the control and identify a set of required machines with the spare capacity to form a manufacturing cell to process the job. When the job has been completed, the manufacturing cell will be dissolved. The machines released will then become available for other cells to serve other incoming jobs. With this VC concept, manufacturing system can organize the appropriate resources to satisfy the customer demands and realize the rapid reconfiguration. Hence, how to form a suitable VC is a key issue in agile manufacturing. With the development of manufacturing technology and equipment, non linear process plans emerge and improve the performance of manufacturing system with alternative methods to handle increased complexity

The relationship between the machines and products is becoming more and more complicated. Taking into account the dynamic nature of process planning, once and order arrives, the system will select the appropriate resources required to complete the jobs involved and form a number of VC's to cope with the dynamic demand changes.

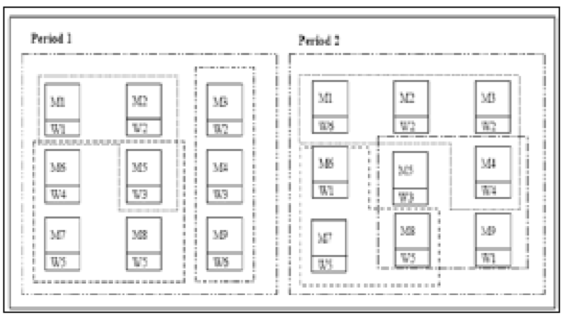

Fig 1: Virtual manufacturing cells over a period

Non Linear process plan:
Non-linear process plans are process plans which comprise different manufacturing alternatives. Such non-linear process plans increase the flexibility of scheduling activities and allow responding quickly to disturbances in the workshop. The automatic generation of a non-linear process plan is realized in different steps:

- The feature based work piece description is transformed into a non-linear sequence of operation steps:
- The resources capable to manufacture: the specified operation steps, are determined.
- The non-linear sequence is converted into a non-linear process plan which is directly usable for scheduling

The process plan for a product should meet the changing requirements with the due consideration of equipment loading and processing efficiency. Thus, the process planning is a complex activity and in the case of a manufacturing system that attempts to meet uncertain demand, process planning takes place frequently. Such an activity certainly influences significantly the control of manufacturing systems.

In the current manufacturing environment, the capacities of a production system are distributed among the different machines. The capacity boundaries of each machine and the operations they can perform are also well defined. Some operations can be performed on more than one machine, and some machines can perform many different operations, which results in the dynamic aspects of process planning. Hence each process plan should contain alternative routes for each operation. It is suggested that because of factors such as the excessive loading of certain machines, the constant change in the products, the changeover required on processing machines between lots, and so on, alternative methods will enhance the performance of manufacturing systems.

Case study:
In this section, a manufacturing company which is currently manufacturing parts in a functional layout is considered; the performance of the company is measured in terms of utilization, throughput, average flow time and average WIP in the system. Due to turbulent environment, the manufacturing company is forced to vary its product mix and volume. While doing this, the company faces challenges in terms of its performance and delivery.

Proposed methodology:
A case of study demonstrating the methodology is presented. This methodology offers a efficient ways for organizing the resources and constructing the virtual cells. The details procedure of forming the virtual cells and planning the production of some parts in a job shop are illustrated here. the project is about simulating the above case in the current and the proposed environments by varying product mix and volume. The process of simulation is carried by the tool " WITNESS 2006". The performance of the existing and the proposed layouts is carried out using interaction plots and a suitable layout is suggested at the end of this work.

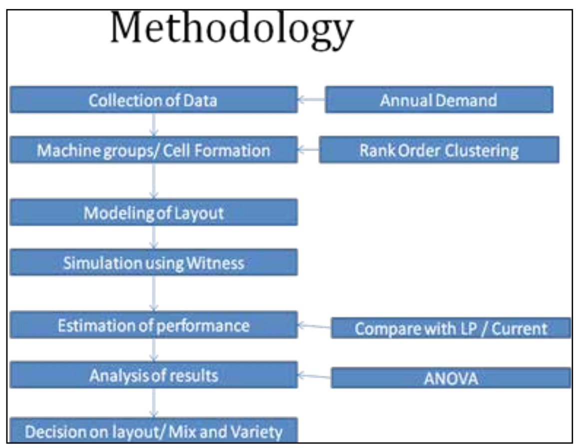

Figure 2, provides a brief overview of the process followed by Taguchi's approach to parameter design

Scope of the work:
Developments in the market place, as well as technological developments, stimulate the thinking about alternative layout (physical) and control (logical) principles in manufacturing. The manufacturing sector has become increasingly competitive as markets become more global. As a result, producers of goods are under constant and intense pressure to quickly and continuously improve their operations by enhancing productivity, quality and customer responsiveness. Many firms, furthermore, are faced with a turbulent environment indicated by high demand variability, frequent changes of the product mix, a high number of unique orders, a high variation of processing times, and variable production sequences. This situation requires an agile manufacturing situation in which the physical and/or logical layout can be easily adapted in order to gain a competitive performance. Cellular manufacturing and other approaches that integrate layout changes and control

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changes provide opportunities for production organizations that face these new requirements.

Illustrative example:
The detailed information about the demand, machines, parts, routing and the demand are shown in table 1 and 2 respectively

Part Type	Demand (Qty)	Part Type	Demand (Qty)
P1	1500	P11	150
P2	100	P12	100
P3	100	P13	100
P4	550	P14	100
P5	100	P15	100
P6	200	P16	150
P7	100	P17	100
P8	1000	P18	250
P9	200	P19	100
P10	100	P20	100

Tale 1: Part-Demand Matrix

Part/ Machine	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
P1	1	1					1					
P2	1	1					1					
P3			1		1	1						
P4			1		1	1						
P5				1	1				1			1
P6	1		1		1	1						
P7								1		1	1	
P8				1					1			1
P9								1		1	1	
P10				1					1			1
P11			1	1				1		1	1	
P12				1					1			1
P13			1		1	1						
P14	1	1					1					
P15	1	1					1					
P16			1		1	1	1	1		1		
P17				1			1		1		1	1
P18								1		1	1	
P19	1	1					1					
P20								1		1	1	

Table 2 : Part-Machine Matrix

Rank order clustering:
BINARY ORDERING ALGORITHM (RANK ORDER CLUSTERING)
Rank Order Clustering Provides an efficient routine for taking an arbitrary 0 – 1

Machine-part matrix and reordering the machine rows and part columns to obtain a nearly block diagonal structure. Block diagonal means that a machine–part matrix can be partitioned such that the main diagonal boxes contain

Mainly 1s and less number of 0s but the off-diagonal boxes contain only 0s. The on-diagonal boxes show the natural group for the manufacturing plant.

Binary Ordering Algorithm:
- o Consider the rows and columns as binary strings
- o To get block diagonal form, the similar rows should be brought together and similarly similar columns
- o A row is a binary number, then similar rows have similar values; similarly we can envision columns
- o That is, we can reorder rows or columns in the descending order of their binary value
- o Ending orderings are not unique for a given data set.
- o Different starting orderings may yield different ending orderings.
- o It provides starting point for most of the grouping procedure

We perform Rank order clustering in this paper by using binary ordering algorithm for the formation of Part-Machine groups and is shown in table 3

Part/ Machine	M1	M7	M2	M3	M5	M6	M8	M10	M11	M4	M9	M12
P1	1	1	1									
P2	1	1	1									
P14	1	1	1									
P15	1	1	1									
P19	1	1	1									
P6	1			1	1	1						
P16		1		1	1	1	1	1				
P3				1	1	1						
P4				1	1	1						
P13				1	1	1						
P11				1			1	1	1	1		
P7							1	1	1			
P9							1	1	1			
P18							1	1	1			
P20							1	1	1			
P17		1							1	1	1	1
P5					1					1	1	1
P8										1	1	1
P10										1	1	1
P12										1	1	1

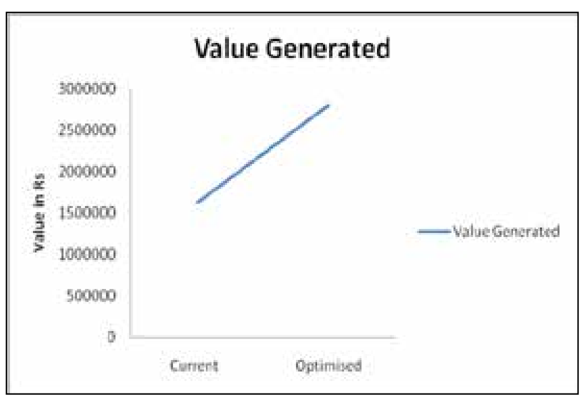
Table 3: Cell grouping using Rank Order Clustering

Optimization using Linear Programming:
Optimization is a technology for calculating the best possible utilization of resources (people, time, processes, vehicles, equipment, raw materials, supplies, capacity, securities, etc.) needed to achieve a desired result, such as minimizing cost or process time or maximizing throughput, service levels, or profits. Optimization technology improves decision making speed and quality by providing businesses with responsive, accurate, real-time solutions to complex business problems.

Optimization can benefit your business and profitability in many ways:

- Optimized applications generate solutions faster than any other software
- Optimization automates your solution process and verifies that the solution adheres to your business rules
- Optimization dramatically improves business flexibility, responsiveness to changing circumstances, and ability to test "what if" scenarios
- Optimization focuses decisions and resources on business priorities

In this paper we have used Linear programming (LP) as a mathematical method for determining a way to achieve the best outcome (such as maximum profit or lowest cost) in a given mathematical model for some list of requirements represented as linear equations. The results of LP over the existing / current layout is shown in graph 1



Graph 1: Economic comparison of current and optimized methods

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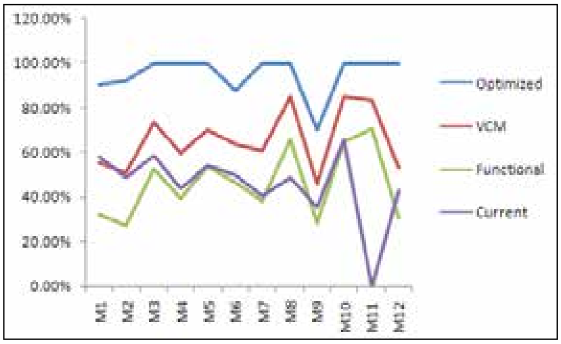
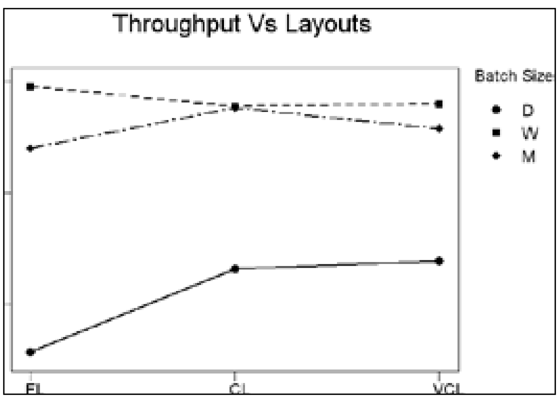
Simulation using Witness 2006:
The role of simulation is to evaluate practical alternatives available either in support of major strategic initiatives which might involve large financial outlay, and time. Examples of such evaluations include changes to the product mix, increases or decreases in volumes, improvements in throughput, shorter lead times and improved customer response times.

The case is analysed and simulated for the existing layout and the proposed layout (VCM). The performance measures of the industry are evaluated when it is manufacturing parts through virtual cellular layout and a comparative study is made. The results of the simulation are presented in the graph 2

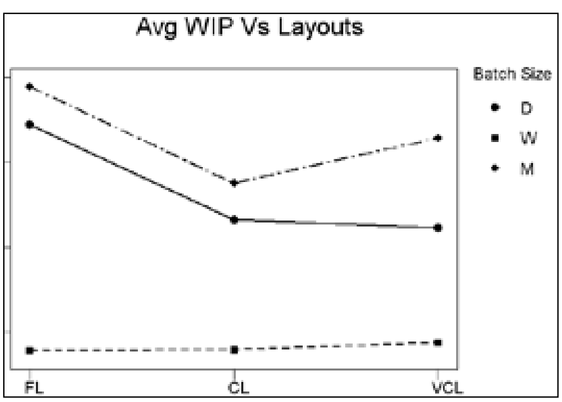


Graph 2 : Comparison of machine Utilization

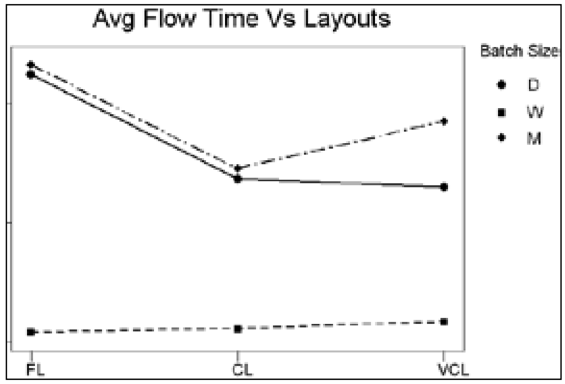
The batch sizes of Daily (D), Weekly(W) and Monthly (M) are considered for the study



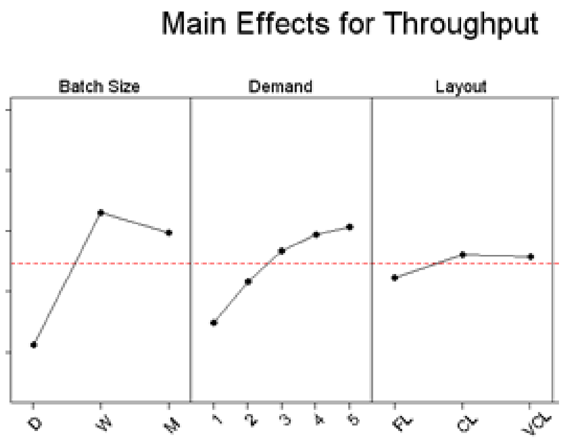
Graph 3: Throughput Vs Layouts



Graph 4: Average WIP Vs Layouts



Graph 5 : Average Flow time Vs Layouts



Conclusions:

1. From the interaction plot it is inferred that throughput has direct relationship with demand for all the batch sizes.
2. For all the demand variations, functional layout is giving poor performance due to higher WIP and Scheduling issues. Virtual cellular layout is giving nearly equal throughput when compared with cellular layout due to the flexibility.
3. Overall throughput is proportionally decreasing due to unbalanced machine load for all the layouts.

Although this paper has answered some aspects of routing flexibility, through put times, average WIP and machine utilization, many interesting dimensions remain. It is worth to include due date considerations, the cost of material handling, disturbances due to machine non availability due break down or planned maintenance.

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