Propose an Algorithm for Manufacturing Cells Formation (MCF): A CIM Perspective

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المستخلص:

ان التطبيق الكفوء لنماذج التصنيع المتكامل باستخدام الحاسوب وبكل ما يعنيه معنى التكامل سيمكن الصناعات من مواجهة المنافسة المحلية والعالمية وبدرجة عالية من الثقة. تم في هذه الدراسة الاعتماد على فلسفة تكنولوجيا المجموعة لتجميع الاجزاء ضمن العوائل والمكائن ضمن الخلايا. كما تم انشاء خوارزمية لتكوين الخلايا التصنيعية مستندة الى نماذج التصنيع المتكامل. لذا تم تعريف بعض المعايير المهمة ودراسة اثرها على اداء النظام. سلطت الخوارزمية المقترحة الضوء على السلوك الديناميكي للخلايا الانتاجية، كما انها تسمح بالحصول على تدفق انسيابي للمعلومات مما يضمن بالتالي الحصول على ترتيب انسيابي للخلايا، وتعديل الترتيب غير الفاعل.

Abstract:

The efficient application of Computer Integrated Manufacturing (CIM) models in a fully integrated manner will help the industries face the global and local competition with a high degree of confidence.

In this study, the Group Technology Philosophy of grouping parts in families and machines in cells was considered. An algorithm based on the CIM models for manufacturing cells formation (MCF) was developed. To do this, some important criteria identified, and their impact on the system performance studied. The proposed algorithm sheds light on the dynamic behavior of the manufacturing cells and it allows obtaining

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information flow, in order to obtain a flow shop layout for the machine cells, and modifying inefficient cells layout.

Keywords: **Group Technology, Manufacturing Cells, Computer Integrated Manufacturing, Intercellular Moves, Rerouting Jobs.**

1- Introduction:

The difficulty in today's manufacturing environment is that manufacturing can no longer look forward to many years of stable high demand. This is because product redesign is continuously happening and a product's lifecycle in the marketplace is constantly under attack from improved versions incorporating the latest design features. Therefore, manufacturing seen as a new competitive weapon and, as a result, manufacturing firms find them in a totally changed environment.

The application of Group Technology (GT) in advanced production systems facilitates the process of implementing CIM by simplifying the information control required and providing necessary information about process and production flow. The availability of a coding system for parts and production sequence, together with a database helps to design CIM models and techniques. Grouping of parts and machines into cells leads to cost savings in setup time, labour, tooling, rework, scrap, machine tool maintenance, and work-in-process. Other intangible benefits include highly reliable delivery time, higher management efficiency, lower product throughput time, improved response to customers, and better product quality.

Since Manufacturing Cells Formation (MCF) dedicated to the production of one or more families of parts, the establishment of families will control the creation of cells. The difficulty in this area arises from the problem of identification of similar parts to be grouped in a family, and

then grouping of machines processing these families of parts in a cell. In practice, it is desirable for parts to be processed entirely within a single cell so that no material flow between different cells exists. This can be accomplished, in general, only by duplicating machines in different cells. Nonetheless, this procedure does not guarantee that the resulting cells are organized like flow shops [1].

To remove such difficulties, it requires building a CIM model based on the need of an accurate data and proper information. The need exists for developing analytical tools that may be used to evaluate the performance of a GT system by proposing an algorithm for manufacturing cells formation. The proposed model is discussed in section 8.

2- The Objective of the Study:

The main aim of this study was to identify and evaluate the performance of GT implementations, and the effect of applying Information Technology techniques (IT) on Manufacturing Cells Formation process.

3- The Importance of the Study:

The importance of this study lies in the following:

a) Since the global competition requires that manufacturing industry – besides the skill and the experience accumulated in the shop practice – should increasingly utilizes practical and proven techniques of Computer Aided manufacturing for rapid and cost effective process design and manufacturing, The need exists for developing analytical computerized tool that may be used to evaluate the performance of a GT system in general, and cells designing in particular.

b) One of the core problems in evaluating a GT system and cells formation process is the lack of a single criterion of measurement.

c) Since any changes may be occur in customer demand or product design, the immediate effect would be on the product mix. This reflects on the process of grouping parts families and finally on manufacturing cells formation.

d) Applying Information Technology (IT) techniques can be the basis for effective and efficient access control in cells manufacturing and layout. This offers opportunities for smoother integration with the overall Information System (IS).

4- Related Works:

Most of the major results in the literatures on MCF have been discussed by Nicoletti et al. (1998) [1], Burbidge (1975) [4], Hyer and Wemmerlov (1982) [5], Ajang (1997) [7], Foulds and Wilson (2003) [8], Gupta and Tompkins (1982) [9], Selim et al. (1998) [11], Vakharia (1993) [12], and Wang (1998) [13]. Several mathematical methods of cell design in GT have been developed in these studies, and relevant literatures are reviewed.

To satisfy the conflicting demand of today's markets, research trends focusing on the application of CIM models in manufacturing industries has been emerged. The realization of CIM requires effective integration of a number of available advanced manufacturing technologies AMTs. Many variations in manufacturing methodologies were developed and proposed by researchers to revitalize the manufacturing industries.

Most of these researches have been discussed by Nagalingam, and Lin (1999) [14], Tucker and Leonard (1994) [15], Lin (1997) [16], and Gunasekaran et. al. (1994) [17].

5- Computer Integrated Manufacturing (CIM):

Computer Integrated Manufacturing (CIM) represents the integrated application of computer technology to manufacturing in order to achieve the business objectives of the firm: reduce inventory investment, reduce manufacturing lead times, reduce cycle time, improved utilization of plant and labour, and improved control of the total manufacturing system [2].

In the early 1970s, using computers for tasks proved cost – effective. Since then, there has been an explosive growth in Computer - Aided Design[1] (CAD), and Computer - Aided Manufacturing[2] (CAM), the cornerstones of Computer Integrated Manufacturing. CIM is the phrase used to describe the complete automation of a manufacturing plant, with all processes functioning under computer control and digital information tying them together [3].

6- Group Technology Philosophy (GT):

Group technology is defined by Burbidge (1975) as "the total of measures to be considered in order to make batch production profitable when using the particular basic solution of group layout" [4]. So, GT is a

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([1]) CAD is the use of computers in interactive engineering drawing and storage of design.
([2]) CAM is the use of computer technology to generate data to control part or all of the manufacturing process.

philosophy seeks for creating families of parts and groups of machines, which referred to as cells, processing these parts. It has been treated as a manufacturing strategy to improve the performance of the whole manufacturing system.

It seeks to rationalize small and medium sized batch production by capitalizing on design and \ or manufacturing similarities among component parts [5]. It is a part classification technique used to categorize parts according to one of two possible similarities: part geometry or, processing similarities. It is generally used to create part families which can then be processed in single cell [6], (figure 1 shows a common manufacturing cell). The advantage of creating part families based on processing similarities (process routings) over part geometry (geometrical groupings) is that the information necessary to create these families is readily available whereas effective geometric coding of all parts can be a time consuming process in term of machine utilization and part processing sequences.

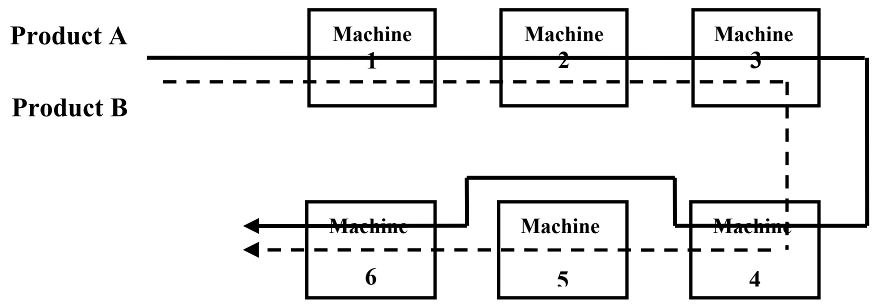

Figure 1: A Manufacturing Cell. (Kilpatrick, 1997)

By grouping similar parts, the manufacturing process for a family of parts is simplified. Group technology is a philosophy that implies the

notion of recognizing and exploiting similarities in three different ways by [3]:

a) Performing like activities together.

b) Standardizing similar task.

c) Efficiently storing and retrieving information.

7- Types of Group Technology Cells Layout:

Cells layouts can be U-shaped or a segment of a line allowing a self-organizing, multi-skilled group of fewer people. Shorter processing times, better team attention to quality problems, reduction of work progress, lower handling costs, and simpler scheduling can be achieved [3]. There are three traditional basic forms of GT layout used to design families of machines and manufacturing cells (workstations); they can be outlined as below [7]:

7-1 GT Center: It is developed from the functional layout, here machining centers and Numerically Controlled machines (NCM) are used. It is appropriate where large machines, which are difficult to be moved, have been installed, and where there is no need to re-layout most the work centers depending to the product mix, as it shown in figure 2.

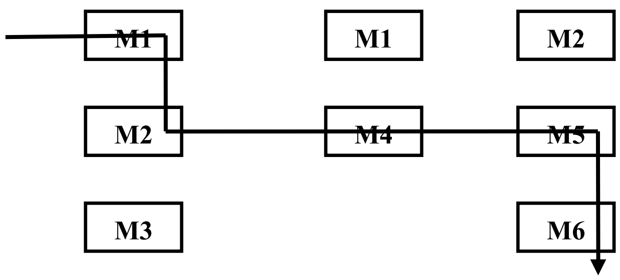

Figure 2: Group Center Layout. (Ajang, 1997)

7-2 **GT Cell: In this form, the way of organizing machines is by their existing in a close proximity, which rationalize the operation sequences and make them more flexible, and simplify the production control. Figure 3 shows this type.**

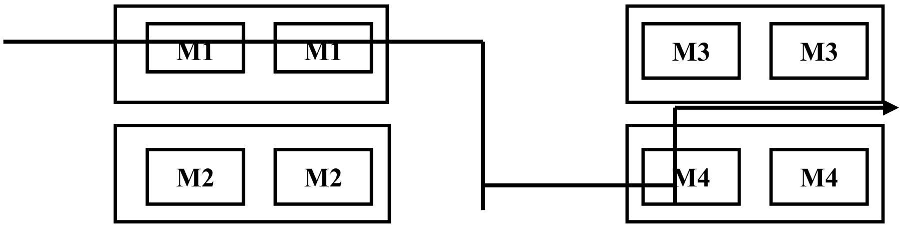

Figure 3: Group Cell Layout. (Same source above)

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7-3 **GT Flow Line: It represents the highest class of rationalizing for GT manufacturing systems. It is used when all parts assigned to the group follow the same machine sequence. The flow line system requires periodic work program such that the different part families can be made according to the updated technological information that lead to the most optimal loading and operation sequence, as is shown in figure 4.**

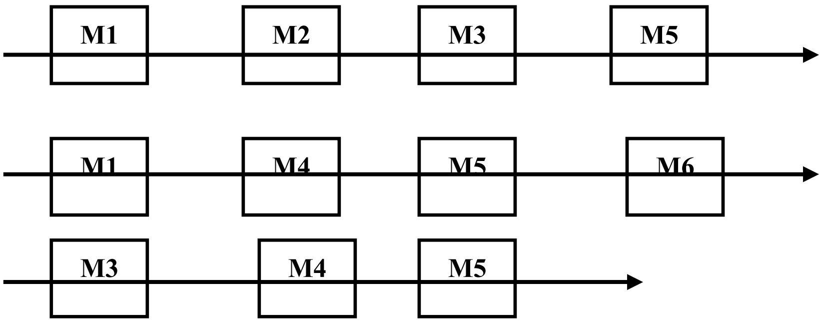

Figure 4: Flow line cell layout. (Same source above)

GT does not specialize in grouping families of machines only, but it is a tool to find the best arrangement of data which be used in design and

manufacturing, storing these data, and retrieveling them for future referencing. Foulds & Wilson (2003) concluded the activities required for the formation of a system of manufacturing cells as [8]:

a) Assigning part families to groups of machine types,

b) Finding lot sizes of the parts produced,

c) Determining the number of machines needed of each machine type,

d) Assigning parts to individual machines, and

e) Grouping the individual machines into cells.

It is often important in practice to be able to reassign parts to different machine types in order to create better cell system configurations. This may involves extending the set of parts that certain individual machines can process. Such extensions may be cheaper than simply purchasing additional machines. Thus, there is the possibility in cell system formation, of machine modification to reduce intercellular moves.

8 – The Proposed Algorithm for MCF:

A cell is a self- sufficient unit, in which all operations to make a family of parts, components, or complete products can be carried out. The cell is like a mini-factory within the factory which a cell team can manage as their own operation-a server to other operations. Thus, client-server relationship can be emphasized.

Since the first requirement of GT is to obtain a reliable database system including parts drawing, tooling design, and production sequence for each part, then using any coding method to code parts, and finally storing the design and manufacturing data for retrieval when needed for

future purposes. There are many criteria of cells design must be considered when formation cells; they include:

8-1 Cell Size: The use of a small number of multi-purposes equipments make the factory seems like a small one, such the computer numerically controlled machining centers. Cells can be designed by choosing specific criteria such as: shapes and sizes, names, or process requirement. Cells formed in this way will result in well defined families that can be made in a single cell if the work load balance is achieved. The cell size would have a damping effect on the intercellular moves caused by a sudden change in the product mix. For smaller cells, the number of intercellular moves would be greater than in the case of larger cells. Now, if the cell size were large, parts would be routed to another machine within the same cell.

The application of CIM models provides accurate data to choose between a large cell size with fewer moves, and a smaller cell with more moves. The information needed to determine the number of intercellular moves obtained from the historical data, management experiences, routing information, process constraints, design departments, and production planning departments.

8-2 Intercellular Moving: In the process of grouping machines and cells, rarely does each group of machines provide for all the machining requirements of the family of parts assigned to it. This results in the necessity to allow for some interaction between groups. The alternative to interactions between groups is to increase the size of the groups in an effort to integrate interacting groups to form one large group. This alternative poses problems of production control as the groups tend to

become too large. Some of the specialization obtained by grouping is lost with increases in group size [9].

8-3 Length of Moves: If the cell size is large, the number of moves may decrease but the moves within the cell will become longer. For purposes of control and standardization in tooling and material handling achieved, flow within the cell is preferred to flow between cells. At this point, the designer must determine the optimum size of a cell, distances between machines within a cell, number of similar machines within a cell, and number of intercellular moves.

8-4 Product Mix: Each cell must be capable of satisfying almost all the production requirements of the part family assigned to it. In case of short-term change in product mix, the immediate effect would be an increased number of intercellular moves as parts needing machining on a particular machine in a cell might have to be routed to a similar machine in another cell owing to lack of capacity within the first cell.

8-5 Lot Size: With traditional methods of manufacturing, a reduction in batch size would result in higher manufacturing costs due to an increased cost of set-ups. GT philosophy has invalidated this inverse relationship between lot sizes and manufacturing costs. The MCF offers the potential to reduce set-up costs, as small batches of products belonging to the same family can be processed together.

8-6 Cells Controlling: The controlling on manufacturing cells must be considered. In case of formulating large sized cells, it must be noticed that the control on such cells would be executed. On the other hand, if the cell size is small, the control on the performance of such cells will be better than in larger cells.

8-7 Machines Loading: One of the assumptions made by must of the GT literature is that demand for the products is uniform. Now, in the case of small batch production, an assumption of uniform demand is unjustified. If the demand was uniform, incoming orders could be consolidated and larger batch sizes planned. This assumption of uniform demand could lead to problems of machine loading in a period when demand may be significantly higher or lower than the average. If a product demand is higher than the average in a period, then the required capacity may exceed the available capacity. There are three alternatives to deal with such a case:

a) Either the job waits in the cell until capacity becomes available,

b) Or it is rerouted to a similar machine in the same cell,

c) Or it is rerouted to a similar machine in another cell, which may be idle at that time.

The trade – off here would be to choose between a larger cell size with fewer moves but less control, and a smaller cell with better control but more moves.

8-8 Rerouting Jobs: If the job cannot be rerouted to a machine within the same cell, machines of the same type in other cells are examined. When rerouting to another cell is considered, a penalty is incurred. This may be due to the inefficient methods of production at the alternative machine, or because of extra work in production planning as cell definitions are violated. If the operation due date can be met by processing on this machine, then the job is rerouted to the other cell. If the due date can still not be met, then the job is filled in the queue of the machine it was originally assigned to. The finished job goes to the next machine.

8-9 Process Reengineering: Many companies are reengineering their organizational structures and roles, as well as manufacturing processes, as they strive to become agile, customer-focused, and value driven enterprises. Business process reengineering BPR is the "redesign of the organization ,culture, and business processes using technology as an enabler to achieve quantum improvements in costs, time, service, and quality" [10].

Since families' formation and machines grouping are the most important steps of GT, which reflected on the characteristics mentioned above, the difficulty in this area arises from the problem of identification of similar parts to be grouped in a family, assigning of parts to individual machines, grouping of individual machines into cells, and modification of individual machines to increase their part processing capability. The proposed algorithm for MCF solves these problems; it requires building a database model based on the need of an accurate data and proper information, which illustrated in fig. 5. Data collection techniques must be available to collect data from the manufacturing cells. It requires the employees to gather the data and later it is compiled on an automated system that requires little human participation. The data collection system consists of various paper documents, terminals, and automated devices located through the plant.

We can see that cells formation cannot successfully accomplish without taking into account both the production system and machine or operation levels. Each level's operation interacts, and therefore places constraints or functional requirements on the adjacent level. The proposed model handles three types of data, which generated from CAD and CAM functions, as shown in figure 6, by using all those data and adopting the

proposed algorithm shown in fig. 7 it will be possible to achieve the full benefits of GT philosophy.

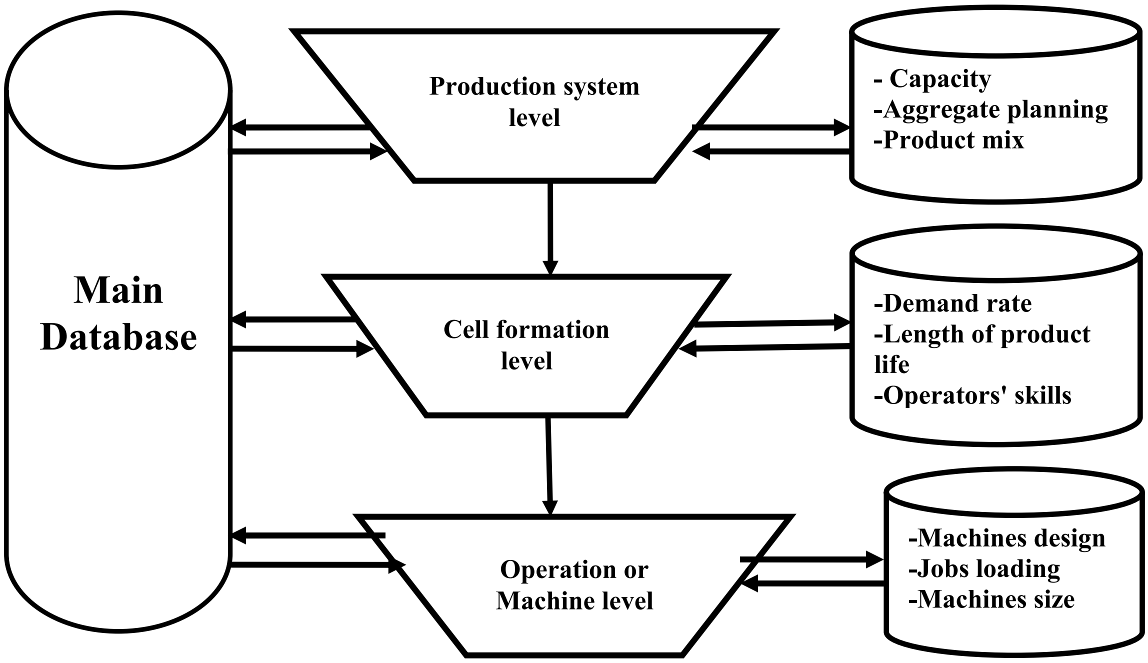

Figure 5: The Main Architecture of the Proposed Model.

stages		
Generation stage data	**Formation stage data**	**Analysis stage data**
- Average of demand. - Available production capacity. - Maximum number of cells in the production facility. - Minimum number of machines to be grouped within each cell. - Number of parts to be assigned to each machine. - Number of set ups. - Set up costs. - Lead times. - Utilization of human resources.	- Cells layout. - Cell capacity. - Groups interactions. - Intercellular moves. - Length of the moves. - Machines size (machine footprint). - Distances between machines. - Due dates. - Handling tools.	- Jobs rerouted to machines. - Process reengineering. - Cells balancing. - Machine cycle time. - Bottleneck machines.

Figure 6: The Data Required for MCF Stages.

9- An example:

A group of three cells is formatted as in fig. 8; there were three kinds of parts processed within these cells, each cell contains number of machines (M_{KC}), where c is the cell number, and k is the machine number. The cells layout is as shown in fig. 9.

part	sequence
A	M_{11} M_{51} M_{42} M_{72}
B	M_{11} M_{21} M_{52} M_{42} M_{32}
C	M_{23} M_{33} M_{43} M_{53} M_{63}

Figure 8: The Sequence of Operations for the example.

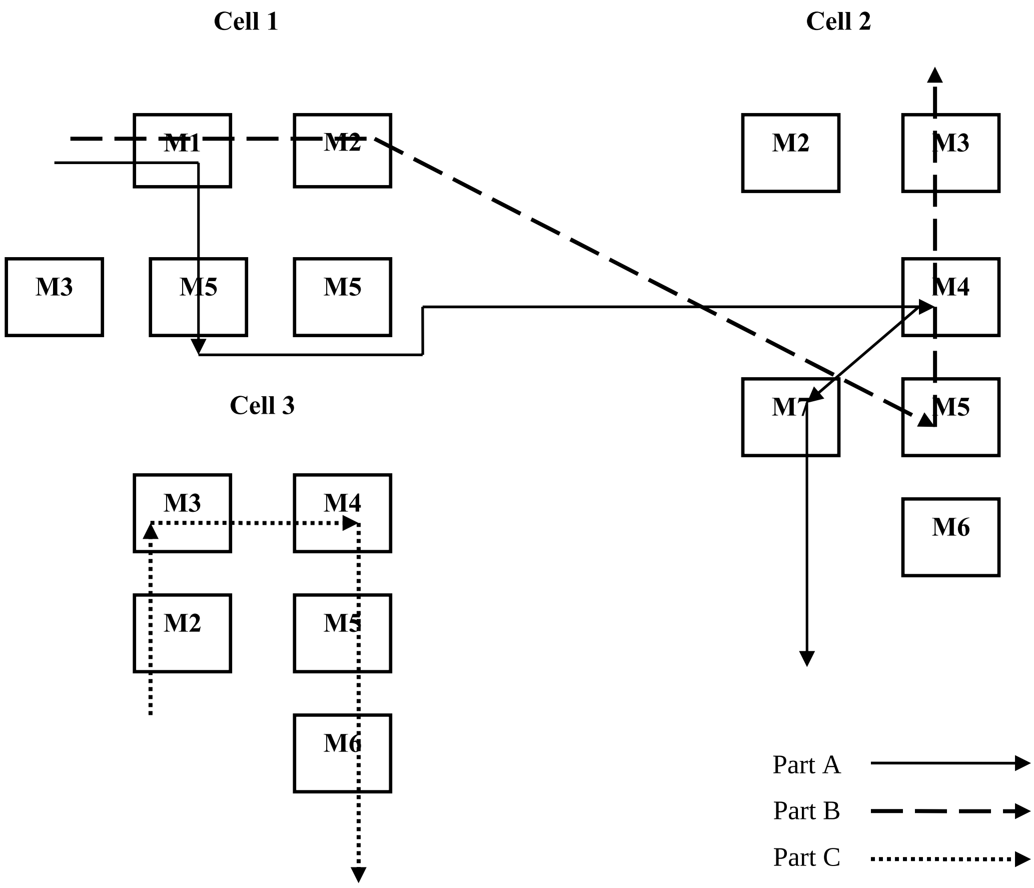

Figure 9: The Cells Layout and Processes Sequence for the Example.

Once a manufacturing cell is designed, the need exists to examine the sequence of each part within each cell. Here, data is available about the machines capacity, due dates, and lot sizes of each part. Machine 4 within cell 2 (M_{42}) is a bottleneck machine. Machine (M_{51}) must be examined, if it is idle then the job of processing part B filled in the queue of the machine. Otherwise, machine of the same type in the same cell or in another cell (M_{53}) is examined. If it is idle, then the job rerouting to it. In order to reduce intercellular moves between cells, machines (M_{43}, M_{33}) are

examined to reroute the job to them. The modified cells layout and the new processes sequences are in fig. 10 below.

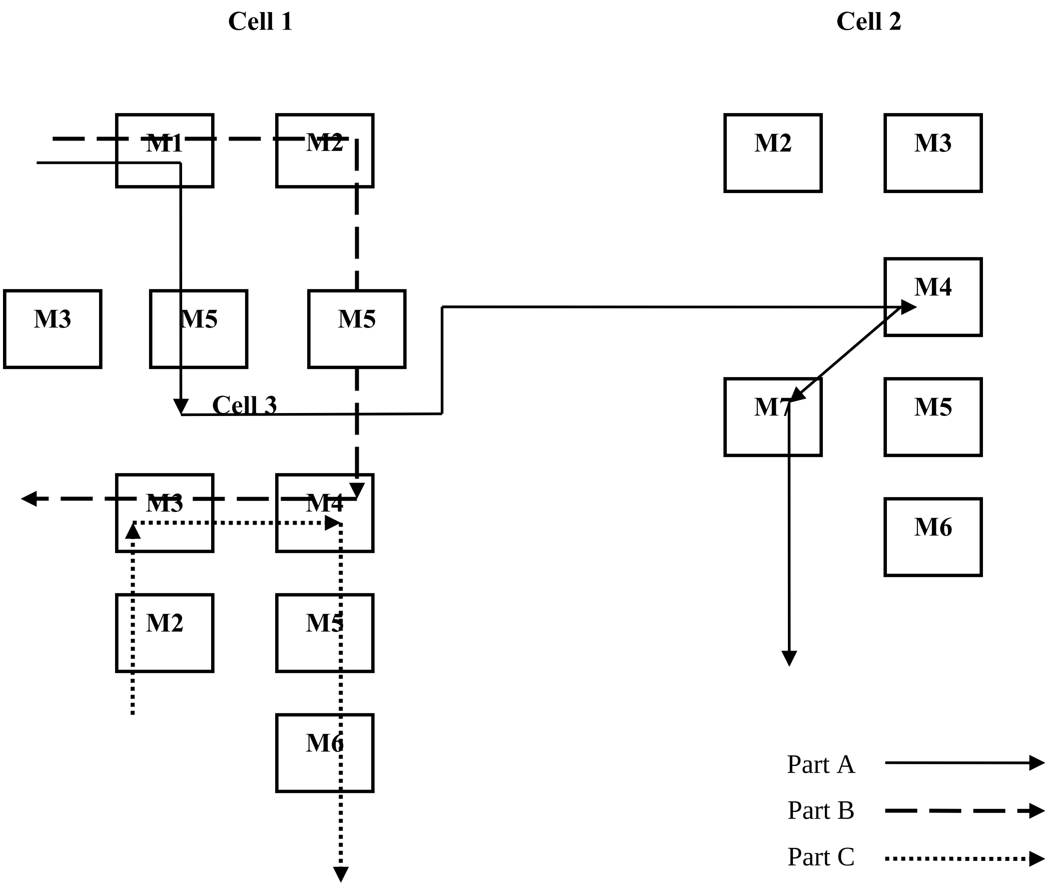

Figure 10: The Modified Cells Layout and Processes Sequence for the Example.

10 – Conclusions and Evaluation of the Proposed Model:

This study proposed an algorithm based on the application of CIM models for manufacturing cells formation. The application of CIM models provides accurate data to choose between a large cell size with fewer moves, and a smaller cell with more moves. Many benefits achieved from adopting this algorithm such as: reduce the number of machines within the cell, reduce the number or length of operations done on the bottleneck machines, if cell size is large, the number of moves may decrease but the moves within the cell will become longer, the control on the performance of small cells will be better than in case of larger cells, reduce set-up costs as small batches of products belonging to the same family can be processed together, better utilization of human resources, and achieve collaboration between the operation management and other departments.

The proposed algorithm sheds light on the dynamic behavior of the manufacturing cells. Many criteria of cells design are considered when formation cells; they include cell size, intercellular moving, length of moves, product mix, lot size, cell controlling, machine loading, rerouting jobs, and process reengineering.

The interaction between cells is important whether in terms of processing or production planning or information flow, and must be considered when designing a manufacturing cell.

The computer system connected directly or indirectly to the production operations. Direct connections are used to:

a) Monitoring the processes in the factory, this monitoring involves the data collection from the factory, the data analysis, and the communication of process-performance results to plant management.

b) Controlling the processes in the factory, by using the computer systems to execute control actions to operate the plant automatically.

On the other hand, indirect connections involve applications in which the computer supports the production operations without actually monitoring or controlling them.

11- Recommendations:

In light of the findings of the study, we may present a number of recommendations aimed at activating the IT implementations in MCF process:

a) Changing of flow line and batch production to cellular manufacturing system to achieve the full benefits of GT philosophy.

b) Installing of numerical controlled machines and computer devices in order to reduce manual operations.

c) Applying GT and adopting the proposed model in areas other than manufacturing, such as marketing, design, distribution, and accounting.

d) For future works, materials handling costs and travel distances have to be considered in the contest of intercellular moves. Inventory costs have to be considered too in order to evaluate a trade – off among various costs.

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