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PARAMETRIC STUDIES IN AUTOMOBILE MANUFACTURING INDUSTRY USING CELL FOCUSED PLANT LAYOUT SIMULATION APPROACH

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Abstract

Cellular layout is having a good recognition and acceptability in manufacturing industries due to space and operator problems. Variable demand, and multi features products have driven automobile manufacturing plants to produce more with quality to face competition. Traditional manufacturing systems, such as job shops and flow lines, cannot handle such environments. Cellular manufacturing, which incorporates the flexibility of job shops and the high production rate of flow lines, has been seen as a promising alternative for such cases. Although cellular manufacturing provides great benefits, the design of cellular manufacturing systems is complex for real-life problems. Existing design methods employ simplifying assumptions which often deteriorate the validity of the models used for obtaining solutions. Two simplifying assumptions used in existing design methods are as follows. First, product mix and demand do not change over the planning horizon. Second, each operation can be performed by only one machine type, i.e., routing flexibility of parts is not considered. This research aimed to develop a model and a solution approach for designing cellular manufacturing systems that addresses these shortcomings by assuming dynamic and stochastic production requirements and employing routing flexibility.

Keywords: CMS, Automobile Industry, Simulation, Layout Reengineering

Introduction

Manufacturing industries are under intense pressure from the increasingly-competitive global marketplace. Shorter product life-cycles, time-to-market, and diverse customer needs have challenged manufacturers to improve the efficiency and productivity of their production activities. Manufacturing systems must be able to output products with low production costs and high quality as quickly as possible in order to deliver the products to customers on time. In addition, the systems should be able to adjust or respond quickly to changes in product design and product demand without major investment. Traditional manufacturing systems, such as job shops and flow lines, are not capable of satisfying such requirements. Job shops are the most common manufacturing system. In general, job shops are designed to achieve maximum flexibility such that a wide variety of products with small lot sizes can be manufactured. Products manufactured in job shops usually require different operations and have different operation sequences. Operating time for each operation could vary significantly. Products are released to the shops in batches (jobs). The requirements of the job shop are a variety of products and small lot sizes dictate what types of machines are needed and how they are grouped and arranged. General-purpose machines are utilized in job shops because they are capable of performing many different types of operations. Machines are functionally grouped according to the general type of manufacturing process: lathes in one department, drill presses in another, and so forth. Figure1 illustrates a job shop. A job shop layout can also be called a functional layout.

In job shops, jobs spend 95% of their time in nonproductive activity; much of the time is spent waiting in queue and the remaining 5% is split between lot setup and processing (Askin and Standridge, 1993). When the processing of a part in the job shop has been completed, it usually must be moved a relatively large distance to reach the next stage. It may have to travel the entire facility to complete all of the required processes, as shown in Figure 1 Therefore, to make processing more economical, the parts are moved in batches. Each part in a batch must wait for the remaining parts in its batch to complete processing before it moves to the next stage. This leads to longer production times, high levels of in-process inventory, high production costs and low production rates.

In contrast to job shops, flow lines are designed to manufacture high volumes of products with high production rates and low costs. A flow line is organized according to the sequence of operations required for a product. Specialized machines, dedicated to the manufacture of the product, are utilized to achieve high production rates.

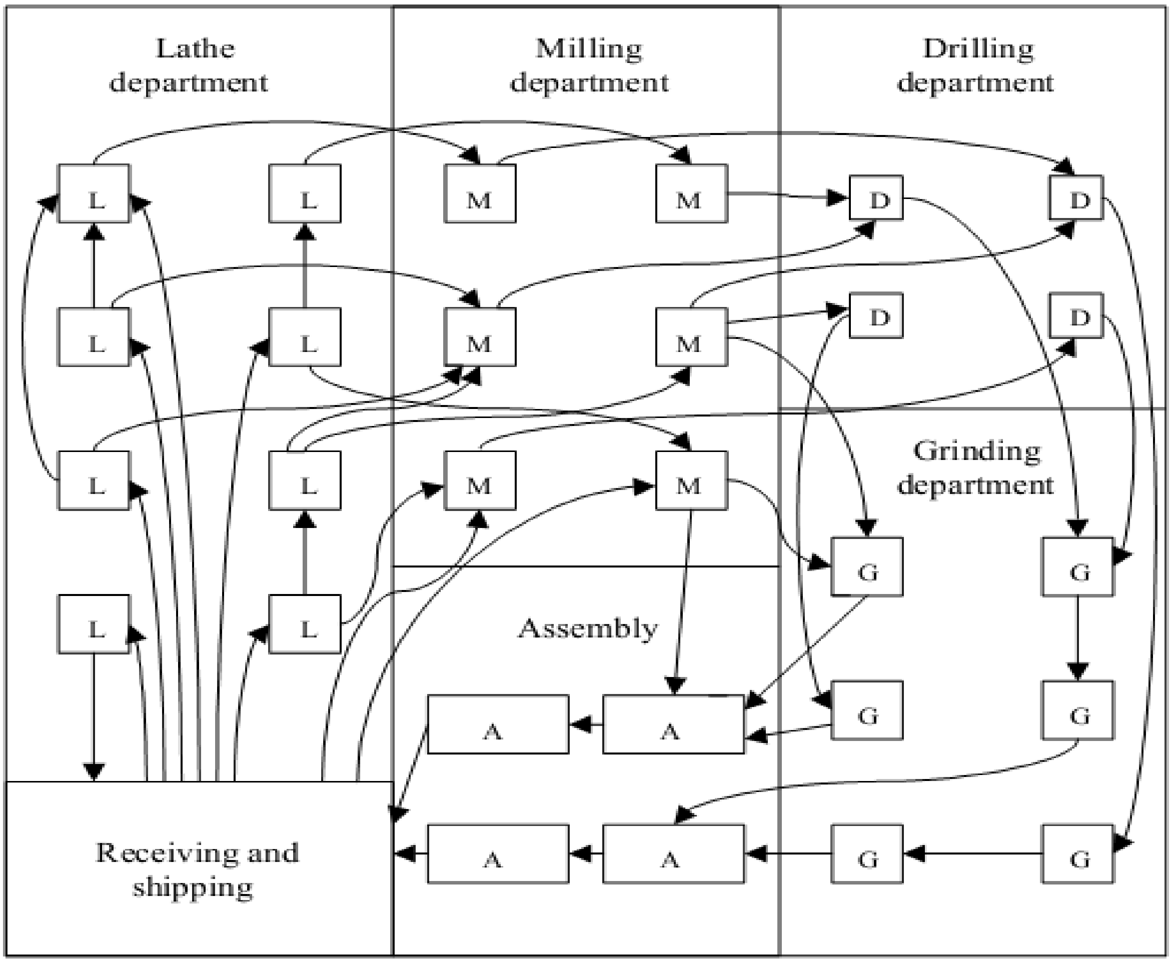

Figure1. Job Shop Manufacturing

These machines are usually expensive; to justify the investment cost of such machines, a large volume of the product must be produced. A major limitation of flow lines is the lack of flexibility to produce products for which they are not designed. This is because specialized machines are set up to perform limited operations and are not allowed to be reconfigured. Figure2 shows an example of a flow line.

As indicated above, job shops and flow lines cannot meet today's production requirements where manufacturing systems are often required to be reconfigured to respond to changes in product design and demand. As a result, cellular manufacturing (CM), an application of group technology (GT), has emerged as a promising alternative manufacturing system. Within the manufacturing context, GT is defined as a manufacturing philosophy identifying similar parts and grouping them together into families to take advantage of their similarities in design and manufacturing (Selim et al., 1998). CM involves the formation of part families based upon their similar processing requirements and the grouping of machines into manufacturing cells to produce the formed part families. A partialt family is a collection of parts which are similar either because of geometric shape and size or similar processing steps required in their manufacture (Barve et al., 2011).

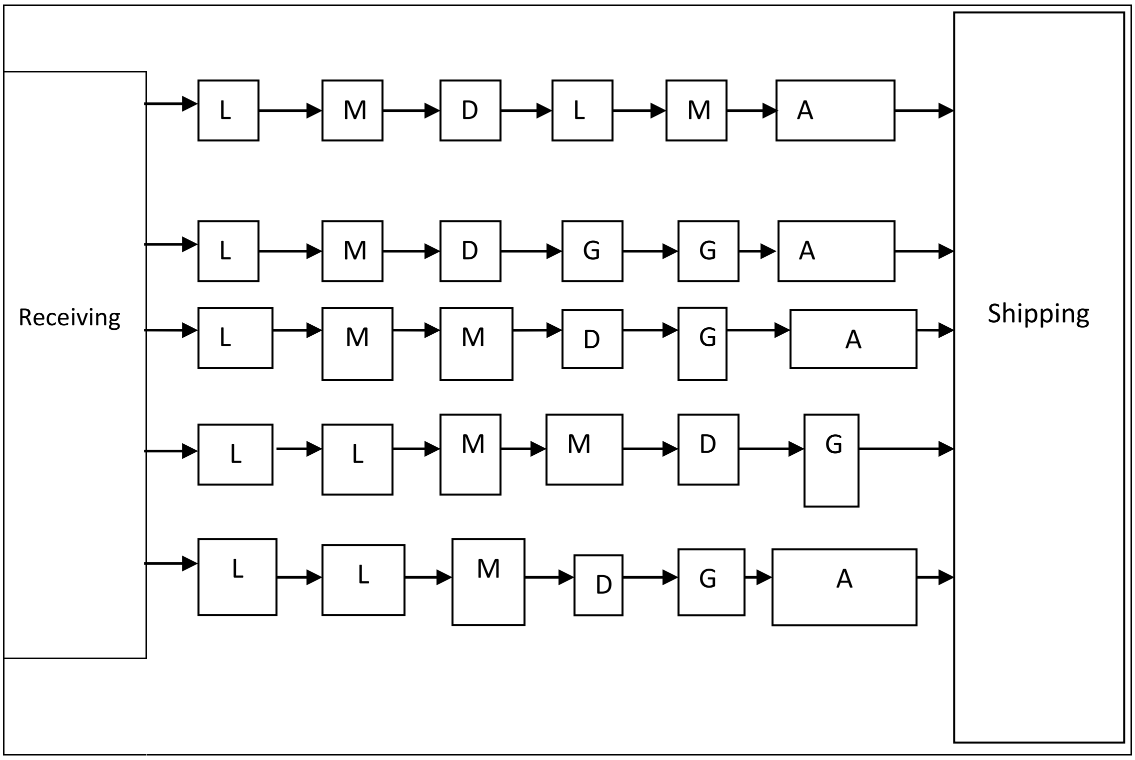

Figure2. Flow Line manufacturing

A manufacturing cell consists of several functionally dissimilar machines which are placed in close proximity to one another and dedicated to the manufacture of a part family. In Cellular manufacturing, part families are formed based on the similarities of design and manufacturing attributes of the parts to be produced. Then a group of machines along with the part families to be produced are formed as cells (Chalapathi, 2012).

The tenet of CM is to break up a complex manufacturing facility into several groups of machines (cells), each being dedicated to the processing of a part family. Therefore, each part type is ideally produced in a single cell. Thus, material flow is simplified and the scheduling task is made much easier. As reported in the survey by (Wemmerlov and Johnson, 1997), production planning and control procedures have been simplified with the use of CM. The job shop in Figure1 is converted into a cellular manufacturing system (CMS) as shown in Figure3. Obvious benefits gained from the conversion of the shop are less travel distance for parts, less space required, and fewer machines needed. Since similar part types are grouped, this could lead to a reduction in setup time and allow a quicker response to changing conditions. On the other hand, in the job shop, each part type may have to travel through the entire shop; hence scheduling and materials control are difficult. In addition, job priorities are complex to set and hence large inventories are needed so as to ensure that ample work is available.

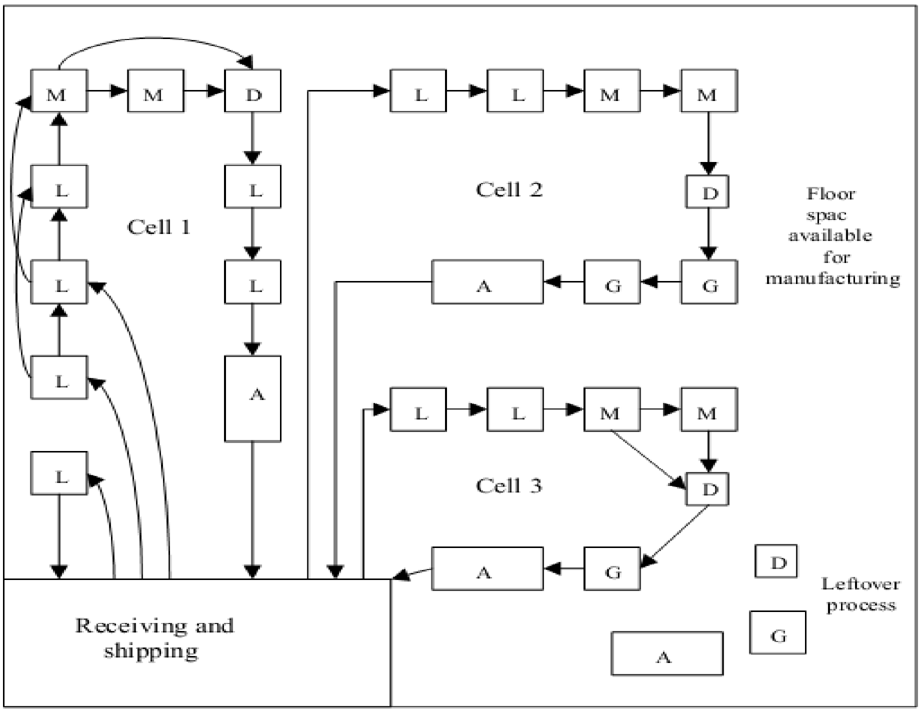

Figure3. Cellular Manufacturing

Once the cellular manufacturing system is designed, scheduling of jobs is essential for the day-to-day production in the machine cells. Scheduling in cellular manufacturing systems is generally complicated. A methodology has been proposed for prioritizing the parts, as well as preparing the total schedules in a cellular manufacturing system. It takes into account, the processing sequences of the jobs, processing and setup times and due dates. The method works out for different dispatching rules viz., first come first serve, shortest processing time, longest processing time, earliest due date and least slack. Various performance measures like the makespan, mean flow time, mean lateness and mean tardiness is used to evaluate the considered dispatching rules. The method gives the sequence of parts to process on each machine and the total schedules for all the operations of the parts(Pasupuleti ,2012).

CM is a hybrid system linking the advantages of both job shops (flexibility in producing a wide variety of products) and flow lines (efficient flow and high production rate). In CM, machines are located in close proximity to one another and dedicated to a part family. This provides the efficient flow and high production rate similar to a flow line. The use of general- purpose machines and equipment in CM allows machines to be changed in order to handle new product designs and product demand with little efforts in terms of cost and time. So it provides great flexibility in producing a variety of products (Chalapathi, 2012).

In conclusion, CM is a manufacturing system that can produce mediumvolume/medium-variety part types more economically than other types of manufacturing systems. If volumes are very large, pure item flow lines are preferred; if volumes are small and part types are varied to the point of only slight similarities between jobs, there is less to be gained by CM. The survey affirms that the greatest reported benefits of CM appear along the dimension of time (manufacturing lead time and customer response time). Thus, CM represents a logical choice for firms whose strategy is time-based competitive manufacturing (Wemmerlov and Johnson, 1997).

There has been a lot research work done by various researchers on cell formation techniques. The majority of the published works on cellular manufacturing pay very little attention towards production planning and control activities of cellular manufacturing. In all situations, where traditional machines are used for operations on parts, concurrent formation of part-families and machine-cells are necessary. In these situations part route-sheets can provide all the details like: sequence of operations, set up and processing times, and number of units to be produced. The number of machines available initially may also be known. The effectiveness of the method depends upon the quantity and accuracy of the information available (Karuna et al., 2012). Many current cellular manufacturing applications are running in a non optimal environment and their performance could be improved by optimizing the parameters. But from the available literature most of the cell formation techniques/algorithm does not discuss the optimal size of the cell and the optimal number of cells, should be formed for a given problem. The techniques required to investigate the effect on different performance measures if the number of cell / cell size/composition of cells varied (Arora et al., 2011). Presently Indian automobile manufacturer is using Advanced Production Technologies (APTs) include all technologies that are used in all steps from computer designing level up to computerized integration of machinery and equipment during production (Suleyman, 2010). APTs are listed in Table1.

CMS Approach

How to incorporate CMS

The implementation process of shedding the traditional manufacturing processes and embracing the drastically different cellular manufacturing techniques can be a daunting task. Management must deal with many issues including: cell design and set up, team design and placement, employee training, teamwork training, as well as other company functional issues. A project team should be put together that consists of management and production employees to handle these changes. Cell Design and Setup should be executed to facilitate the movement of the product through its production cycle and should also be able to produce other similar products as well. The cells are arranged in a manner that minimizes material movement and are generally set up in a “U” shaped configuration. Cellular manufacturing. In cellular manufacturing workers generally operate more that one machine within a cell which requires additional training for each employee creating a more highly skilled workforce. This cross-training allows one employee to become proficient with his/her machines and while also creating the ability to operate other machines within the cell when such needs arise. Teamwork Training should generate camaraderie within each cell and stimulate group related troubleshooting. Employees within each team are empowered to employ ideas or processes that would allow continuous improvement within the cell, thus reducing lead times, removing waste and improving the overall quality of the product. Other issues that must be addressed include changes in purchasing, production planning and control, and cost accounting practices. Arranging people and equipment into cells help companies meet two goals of lean manufacturing: one-piece flow and high variety production.

These concepts dramatically change the amount of inventories needed over a certain period of time.

a. One-piece flow is driven by the needs of the customer and exists when products move through a process one unit at a time thus eliminating batch processing. The goals of once-piece flow is to produce one unit at a time continuously without unplanned interruptions and without lengthy queue times.

b. High-variety production is also driven by the needs of the customer who expect customization as well as specific quantities delivered at specific times. Cellular manufacturing provides companies the flexibility to give customers the variety they demand by grouping similar products into families that can be processed within the same cell and in the same sequence. This eliminates the need to produce products in large lots by significantly shortening the time required for changeover between products.

Table1. Advanced production technologies for Automobile Sector

CAD	CAD is the system that realizes production by carrying the product to computer monitor, carrying out changes desired and transmitting the results as a programme to computerized machines .
CAM	CAM is the technology that providing data processing support to users, by preparing production planning and programmes for coordinate measuring devices and other programmable devices, can operate by using computer controlled techniques until the raw materials are ready for sale .
CIM	CIM is the technology that can manage operational relationships between all the levels in many departments, target the integrity of automation and human by using different technologies instead of carrying out completely an automated organization.
CMS	CMS is the system that aims at obtaining savings got by flow type production used in mass production in workshop-style productions in industries having simple processes.

FMS	FMS is the system in that job parts are carried with material transport systems, coordination is provided with computer system and human factor is minimized in loading and unloading .
R	Robot is designed as multifunction and reprogrammable technologies that can move special parts, devices, parts and materials with programmed movements.

Designing Cells

When designing cells, one must be certain that the prerequisites for cellular manufacturing are in place before attempting to shift to cells (or in designing new cells). The prerequisites include reliable machines, short (<10 minutes) changeover times (for cells which manufacture multiple part types), and an able workforce. One can quickly see that cellular manufacturing cannot be successfully accomplished without taking into account both the system and the machine (Refer Figure 4).

Each level's operation interacts and therefore places constraints or functional requirements on the adjacent level. One must keep in mind both the big picture (the production system) as well as the smaller picture (machine or operation design) when designing a cell or an array of cells. At the system level one must take into account customer demand rate (which determines the Processing time), length of product life, and skill level of the operators. In the process or machine level one must be careful to design machines which are ergonomic, easy and fast to load and unload (proper filtering), have minimal changeover times, and machine footprints (the rectangular size of the machine on the floor) which reduce operator walking distances. Only if all these issues are considered in designing cells will the full benefits of cellular manufacturing be achieved.

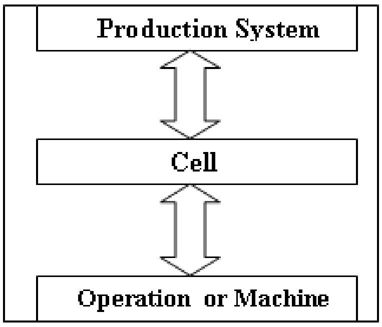

Figure4. Cell Adaptability in Plant

Cell Design Methodology

When moving to cellular manufacturing, one must remember that cellular manufacturing requires quick (<10 minutes) changeovers, reliable machines and a willing, able (cross trained) workforce.

1. Begin with a finished product that will be sold as is to customers. For the final product: translate demand from customers into a Processing time for each individual part in

the final product. For processing time use 7 hours 40 minutes = 27,600 available seconds per shift (or adjust depending on the labor contract). Then assess how long the product will be in operation, and the likelihood of design changes, and their impact on the process, in terms of fixturing, machining, etc.

2. Break out parts according to size and weight. Those parts that are too large (require two hands), too heavy (>10lbs) or too small (parts which can be grabbed between two fingers may present handling difficulties) are candidates for automated material handling systems, i.e. transfer lines.

3. For remaining parts, obtain estimates of machining/assembly times for each operation, including machine time and manual time. Machining times may come from past experience, or a material removal data handbook. Assembly times may come from timed samples. 2 ft / sec should be used for walking speed to estimate operator travel times between machines.

4. Survey existing equipment and assess capacity by comparing the required processing time for each operation with the Processing time. If designing or buying new equipment, buy machines with enough capacity such that predicted customer demand is 85% of capacity (the cycle time of every machine should be less than 85% of the Processing time) using a bottleneck or theory of constraints analysis. Thus, the cell will not be running at 100% of capacity on designing cells to run at less than 100% capacity.) to stay with customer demand, and will be able to increase production should customer demand increase.

Design of Cellular Manufacturing Systems

As described above, the benefits resulting from CM can be substantial. Getting CM in place, however, is not a simple task. Design of cellular manufacturing systems (CMSs) is a complex, multi-criteria and multi-step process. (Ballakur, 1985) showed that this problem, even under fairly restrictive conditions, is NP -complete. The design of CMSs has been called cell formation (CF), part family/machine cell (PF/MC) formation, and manufacturing cell design. Given a set of part types, processing requirements, part type demand and available resources (machines, equipment, etc.,), the design of CMSs consists of the following three key steps:

1. Part families are formed according to their processing requirements.
2. Machines are grouped into manufacturing cells.
3. Part families are assigned to cells.

Note that these three steps are not necessarily performed in the above order, or even sequentially. Part families and manufacturing cells can be formed simultaneously, along with the assignment of part families to the cells. After the design steps have been completed, a manufacturing cell configuration (or cell configuration, for short) is obtained. It is referred to as a cellular manufacturing system (CMS) which consists of a set of manufacturing cells; each cell is constituted by a group of machines and is dedicated to producing a part family. Figure5 shows Layout Planning Design Process to be considered while consideration of CMS as strategy for productivity improvement in automobile industries.

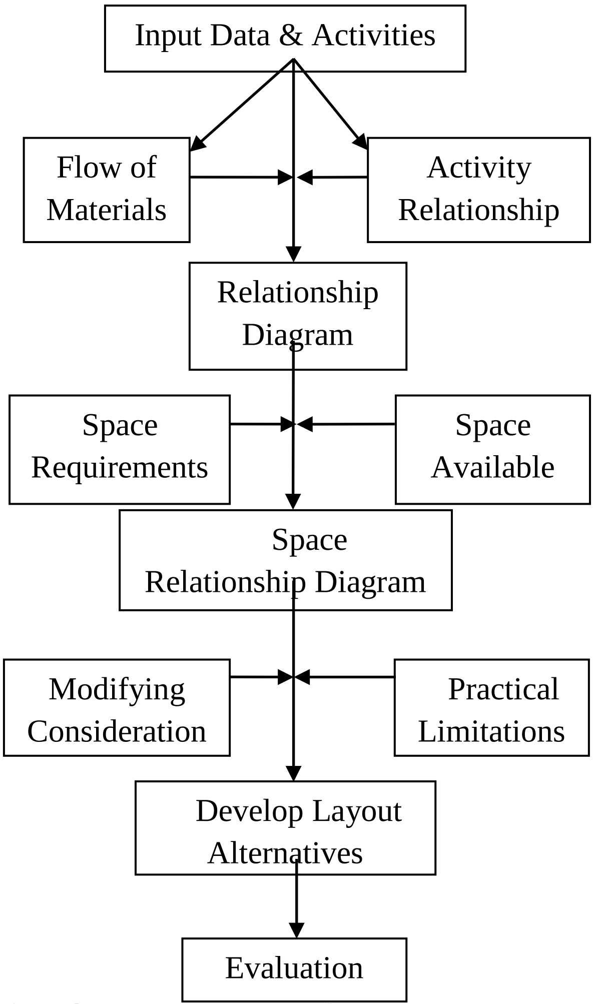

Fig5. The Systematic Layout Planning Design Process

Three solution strategies based on the procedure used to form part families and manufacturing cells. They can be used as a framework to classify existing CM design methods. The three solution strategies are as follows:

1. Part families are formed first, and then machines are grouped into cells according to the part families. This is called the *part family grouping solution strategy*.

2. Manufacturing cells are created first based on similarity in part routings and then the parts are allocated to the cells. This is referred to as the *machine grouping solution*

strategy.

3. Part families and manufacturing cells are formed simultaneously. This is the *simultaneous machine-part grouping strategy*.

In the design of CMSs, design objective(s) must be specified. Minimizing internal moves, distances, costs, and the number of exceptional parts (the parts that need more than one cell for processing) are common design objectives. An exceptional part can be also called an exceptional element or a bottleneck part. In addition to intercell material handling cost, other costs, such as machine cost, operating cost, etc., should be considered in the objective function in order to obtain more valid solutions. The design objective could be the minimization of the total of the sum of intercell material handling cost, equipment cost, operating cost and intercell material handling cost.

Typical costs used in the design objectives are as follows:

1. Equipment cost.
2. Intercell material handling cost.
3. Inventory cost.
4. Machine relocation cost
5. Operating cost.
6. Setup cost.

Typical design constraints in the design of CMSs:

1. Machine capacity. It is obvious that, in the design of CMSs, one of the basic requirements is that there should be adequate capacity to process all the parts.

2. Cell size. The size of a cell, as measured by the number of machines in the cell, needs to be controlled for several reasons. First, available space might impose limits on the number of machines in a cell. If a cell is run by operators, the size of the cell should not be so large that it hinders visible control of the cell. Ranges of cell sizes can be specified instead of a single value of cell size. This would allow more flexibility in the design process.

3. Number of cells. In practice, the number of cells would be set by organizational parameters such as the size of worker teams, span of supervisory authority, and group dynamics. Given a range of cell sizes, the number of cells is determined and the resultant solutions can be compared.

4. Utilization levels. Two levels of machine utilization are normally used. Maximum utilization is specified to ensure that machines are not overloaded. Minimum utilization of a new machine ensures that it is economically justifiable to include the new machine in a cell.

Some of the Software Packages available for CMS Layout design evaluation
(Refer Table2)

Table2. Software Packages for Layout

Block Layout	1. WINSABA 2. FACTORYOPT(in VISFACTORY) 3. SPIRAL 4. CRIMFLO 5. MALAGA 6. MATTFLO PLANOPTSTORM
Group Technology	7. PROFILIER MINITAB SAS PDM Products
Material Flow Analysis	1. FACTORYFLOW (in VISFACTORY) PFAST
Process Flow Mapping	1. VISIO 2. OPTIMA 3. SIMULB 4. ARENA (BPR Template)
Visualization and Performance Evaluation	1. MPX 2. PROMODEL 3. ARENA 4. TAYLOR II 5. QUEST 6. FACTORYPLAN (in VISFACTORY) 7. FACTORYFLOW
Multi-Criterion Evaluation of Layout Alternatives	1. EXPERT CHOICE 2. SUPER TREE
Economic Analysis of Layout Alternatives	1. EASYABC
Capacity Planning and Sizing of Layout Alternatives	1. LINDO 2. CPLEX 3. GAMS 4. MPX 5. FACTORY MODELLER

Some of the Assumptions for CMS design phase in auto industry:

1. The production volume of each component depends on demand for the final product and it is identified based on the production volume of higher level components.

2. Each parent item could have any number from a type of its children.

3. Both machining and assembly operations are just accomplished in one cell and each cell is limited by a lower bound and an upper bound.

4. On the contrary to the traditional models, we assume that the number of cells is one of the unknown variables and it is not predefined.

5 Intra-cell and inter-cell movement times of each component and duration times for setting up and performing machining operations are given. In addition, assembly times and set up times for assembly are also known.

6. The setup times on each machine are specified based on the precedence of parts (Aryanezhada et al., 2011).

Major contributions of the study:

1. Possible Outcome from Implementation of CMS:-

Following parameter can be considered for possible improvements after implementation of Cellular manufacturing system in Automobile plant. Parameters are listed in Table3.

2. Some parameters that to be considered for performance evaluation based on axiomatic design principles are –

a. Raw material stock (days of inventory)

b. Lead time (days)

c. Scrap rate (%)

d. Throughput (unit pairs)

e. Overtime (hours/week)

f. WIP (days inventory)

g. Material move distances (m) (Kulak et al., 2005).

3. To realize rapid design of CMS layout, integrated method of logical and physical layout has more advantages than traditional layout design.

4. Based on process interconnection analysis, research approach for CMS layout planning along cell formation, interactive layout and layout analysis is presented. Based on similarity analysis of processes, logistical cells are formatted which will be initial input for cellular layout.

5. During layout design, layout evaluation technologies such as process interconnection analysis, cell equipment sharing algorithm and material logistic analysis are employed. They are good auxiliary tools for CMS layout design (Huawei et al. 2011).

Table3. Future Performance Improvements from CMS

Types of Benefit	**Number of Responses**	**Average % Improvement**	**Minimum % Improvement**	**Maximum % Improvement**
Reduction In throughput time	In no.	In %	In %	In %
Reduction in WIP inventory	In no.	In %	In %	In %
Reduction in materials handling	In no.	In %	In %	In %
Improvement of operator job satisfaction	In no.	In %	In %	In %
Reduction in number of fixtures for cell parts	In no.	In %	In %	In %
Reduction in setup time	In no.	In %	In %	In %
Reduction in space needed	In no.	In %	In %	In %
Improvement of part quality	In no.	In %	In %	In %
Reduction in finished good inventory	In no.	In %	In %	In %
Reduction in labor cost	In no.	In %	In %	In %
Increase in utilization of equipment in the cells	In no.	In %	In %	In %
Reduction in piece of equipment of required to manufacture cell parts	In no.	In %	In %	In %
Reduction of move distance/time	In no.	In %	In %	In %
Reduction of response time to orders	In no.	In %	In %	In %
Reduction in unit costs.	In no.	In %	In %	In %

6. To take complete benefit of CF, along with grouping parts into part families and machines into machine cells, add workers and tools as third and fourth dimensions of parts and machines respectively to meet industrial specifications (Groover, 1987).

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