CHAPTER 1
INTRODUCTION

1.1 GENERAL

Today’s business scenario faces severe price competition and changing market demands. The customer wants a good quality product at a very competitive price. This forces every production industry to focus on high variety and small volume with customer’s specified quality. The event of changing global scenario on just in time or on time delivery, the manufacturing systems design has undergone various changes from the traditional methods. The trend of business is from few models in large quantity to many models in small quantity in highest order. In this highly competitive environment, markets are heterogeneous and volatile in nature. A manufacturing firm to sustain under the volatile demand condition, its production process has to be configured suitably. The ability to design and operate manufacturing facilities that can quickly and effectively adapt to changing technological and marketing requirements is becoming increasingly important to the success of any manufacturing organization. Hence, manufacturing facilities must be able to exhibit high levels of flexibility and robustness despite significant changes in their operating requirement. The emphasis now is on working closely with customers and suppliers.
1.2 MANUFACTURING REVOLUTION

In traditional manufacturing material moves through successive production operations on machines arranged in process layout. Materials travel over long distance with a lot of cress cross movement and back tracking. There is considerable waiting time between operations which results excessive cost of material handling, large work-in-process inventory, long and uncertain throughput time excess lead time, lack of ownership etc. Manufacturing plays an important role in the economy of every nation. In India, manufacturing accounts for about 17% of the GDP from 12% of employment. National manufacturing competitive council stated Indian manufacturing sector shares three-fourths of all exports from India only. There has been a growth of around 15 percent in this sector in the year 2007. Product and process innovations, technological developments, improved managerial skills, and the availability of low cost workforce are the potential competitive capabilities of India’s manufacturing. There are several other aspects, which the country needs to address in order to improve its competitiveness in the global manufacturing scenario. Industries all over the world have been focusing on the technological and managerial dimensions of their operations to improve their performance and competitiveness. Apart from such tools and techniques, Japan has conceived and evolved many other techniques and practices for improving the organizations performance and competitiveness. Kaizen (continuous improvement), Just-in-time (Kanban), quality circles, total productive maintenance, poka-yoke, zero defects, and cellular manufacturing, etc. are among those techniques and practices that have been adapted particularly by manufacturing industries in various developed and developing countries. The culture of the organization concerned and that of the country, however, have a strong bearing on the extent to which these Japanese manufacturing techniques and practices (JMTPs) make their impact as desired. Ford and Honeycutt (1992), in a
comprehensive article, have discussed the relevance of the culture of a country in understanding the country’s business practices. They have also established that corporate culture is company specific, and therefore generalization of any company-specific observations can be misleading. It is perhaps, for this reason why researchers have been addressing issues like adoption, implementation, and effectiveness of various JMTPs in the manufacturing sectors in different countries.

Our Indian manufacturing organizations ranks 2nd level just after Japanese manufacturing by the Deming awards per country. There are about 13 companies that have won this award and many others are ISO-9000 certified. In a summit during 2005 from Deloitte research stated that till the last couple of years of the 20th century, practices like Statistical Process Control (SPC), Total Quality Management (TQM), Just-in-time (JIT), Total Productive Maintenance (TPM), Cellular Manufacturing (CM) and continuous improvement either failed to serve their purposes in the Indian manufacturing organizations or to even receive any attention from this sector by Chandra and Sastry (1998). In this context and as inspired by the findings like that of Ford and Honeycutt (1992) the author have made an attempt to study the present scenario of Indian manufacturing with reference to the implementation and effectiveness of some popular JMTPs. This has further helped the author to assess the adaptability of these techniques and practices in the Indian context.
manufacturing system and then to a job shop (a process layout). In addition to these three, there is also another type of layout called as a fixed layout.

Figure 1.1 Classification of Manufacturing systems

The above figure indicates, there is an overlap in the systems definition. This overlap results because of the difference in investments possible in different cases and the definition of such systems as desired by the management of the particular plant. For example, though our classification places a cellular manufacturing system between a job shop and a production line, it mentions that a group layout has been observed to work quite efficiently. So the planners of a particular plant might decide to go for a production line for a product, another might choose to group this product with others of the same type and form production cells. However, in most cases, it is not difficult to make a choice about the type of system to be used.

1.3.1 Group Technology

The main driving force behind manufacturing system is the concept of Group Technology (GT). GT as the term indicates similar things together. GT is a method that improves manufacturing efficiency by classifying similar products into families. It has been given by Heragu (1994) thus the key concept...
of GT is to plan a total division of parts or products into groups and families, based on common features shared by all the products considered for introduction into the group. These features share similar production processes or techniques. The main idea behind such a division is to bring similar products/parts together so that costs resulting out of non-value added process, costs due to setups, inventory and material handling can be reduced from the survey of Onyeagoro (1995).

1.3.2 Cellular Manufacturing

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 quick 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 shop and flow shop lines are not capable of satisfying such requirements.

Job shops are the most common manufacturing system in some countries. 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 has been pointed out by Black (1991). Products are released to the shops in batches. The requirements of the job shop shows 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. Figure 1.2 illustrates a job shop. A job shop layout can also be called as functional layout.

Figure 1.2 Job Shop Manufacturing

In job shops, jobs spend 95% of their time in nonproductive activity; much of the time is spent for waiting in queue and the remaining 5% is split between lot setup and processing. 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 1.2. Therefore, to make processing more economical, parts are moved in batches. Each part in a batch must wait for the remaining parts in its batch to complete processing before it is moved 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. 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 setup to perform limited operations and are not allowed to be reconfigured. Figure 1.3 shows an example of a flow line.

![Flow Line Manufacturing Diagram](image)

**Figure 1.3 Flow Line Manufacturing**

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. The only solution to face this challenge is Cellular Manufacturing (CM). As a result CM an application of group technology (GT) has emerged as a promising alternative manufacturing system. 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 part family is a collection of parts which are similar either because of geometric shape and size or similar processing steps required in their manufacture. 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.

The theory of CM is to break up a complex manufacturing facility into several groups of machines called cells. A cell is a group of dissimilar machines physically located in close proximity, such that a part is processed from start to finish in a single unidirectional flow (without backtracking) has been pointed out by Ruiz-Torres and Nakatani (1998). Each being dedicated to the processing of a part family and 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 and flow line is converted into a Cellular Manufacturing System (CMS) as shown in Figure 1.4. 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.
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.

1.3.2.1 Benefits of CM

The advantages derived from cellular manufacturing in comparison with traditional manufacturing systems in terms of system performance has been discussed by Levasseur et al (1995), Singh and Rajamaani (1996) and Wemmerlov & John (1997). These benefits have been
established through simulation studies, analytical studies, surveys, and actual implementations. They can be summarized as follows:

1. Setup time is reduced. A manufacturing cell is designed to handle parts having similar shapes and relatively similar sizes. For this reason, many of the parts can employ the same or similar holding devices (fixtures). Generic fixtures for the part family can be developed so that time required for changing fixtures and tools are decreased, pointed out by Suresh and Meith (1994).

2. Lot sizes are reduced. Once setup times are greatly reduced in CM, small lots are possible and economical. Small lots give smooth production flow has been stated by Singh and Rajamaani (1996).

3. Work-in-process (WIP) inventories are reduced. With smaller lot sizes and reduced setup times, the amount of WIP can be reduced. Askin and Standridge (1993) showed that the WIP can be reduced by 50% when the setup time is cut in half. In addition to reduced setup times and WIP inventory, finished goods inventory is reduced. Instead of make-to-stock systems with parts either being run at long, fixed intervals or random intervals, the parts can be produced either just-in-time (JIT) in small lots or at fixed, short intervals.

4. Material handling costs and time are reduced. In CM, each part is processed completely within a single cell (where possible). Thus, part travel time and distance between cells is minimal.
5. A reduction in flow time is obtained. Reduced material handling time and reduced setup time greatly reduce the flow time has been pointed out in the literature of Shafer and Charnes (1994).

6. Tool requirements are reduced. Parts produced in a cell are of similar shape, size, and composition. Thus, they often have similar tooling requirements.

7. A reduction in space required. Reductions in WIP, finished goods inventories, and lot sizes lead to less space requirement has been pointed out by Singh and Rajamaani (1996).

8. Throughput times are reduced. In a job shop, parts are transfer between machines in batches. However, in CM each part is transfer immediately to the next machine after it has been processed. Thus, the waiting time is reduced substantially rightly pointed out by Singh and Rajamaani (1996).

9. Product quality is improved. Since parts travel from one station to other as single units, they are completely processed in a small area. The feedback is immediate and the process can be stopped when things go wrong.

10. Better overall control of operations. In a job shop, parts may have to travel through the entire shop. Scheduling and material control are complicated. In CM, the manufacturing facility is broken down into manufacturing cells and each part travels with a single cell, resulting in good scheduling and control.
1.3.2.2 Design of CM

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 (CMS) is a complex, multi-criteria and multi-step process. Ballakur showed that this problem, even under fairly restrictive conditions, is NP-complete. The design of CMSs has been called cell formation, part family/machine cell 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 CMS 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 for shortest route is obtained. It is refer to as a cellular manufacturing system (CMS) which consists of a set of manufacturing cells; each cell is constituted of a group of machines and is dedicated to produce a part family. The layout or arrangement of machines in each cell belongs to the layout design problem, and is also considered in this research.

The author suggested 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 solution strategy.

On the whole for the design of CMS, the design objective must be specified. Minimizing intercellular moves, distances, costs, and the number of exceptional parts (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 the design objectives, some of strategic issues such as machine flexibility, cell layout, machine types, etc., need to be considered as a part of the CM design problem. Further, any cell configuration should satisfy operational goals (constraints) such as desired machine utilization, production volume, number of manufacturing cells, cell sizes, etc. The followings are typical design constraints in the design of CMS.

1. Machine capacity. It is obvious that, in the design of CMS, 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 has been given by Askin et al (1997). Given a range of cell sizes, the number of cells are 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 for a new machine ensures that it is economically justifiable to include the new machine in a cell.

1.3.3 Lean Manufacturing

The new control system, which has been termed “pull” to contrast it with “push” systems where product is produced to fill stock, will result in production control on an individual part basis. Under single piece flow parts will be produced at a rate set by the Takt time. This will create a synchronized flow of product and essentially form a linkage between cells. The production system will be transformed into a set of linked cells. The Takt time is the length of time required between successive units of end product, and is determined by the following equation

\[
Takt \ Time = \frac{\text{Total time available}}{\text{Total number of parts to produce} / \text{day}}
\]
In short, the factory must produce a part once in every ‘X’ seconds, where \( X = \text{Takt time} \). The manufacturing lead time and order lead time will be reduced by converting the factory from a job shop to cellular manufacturing. This transition to cellular manufacturing will be accompanied by implementation of improved quality methods, including the transition from final inspection to successive inspections to self checks and finally to installation of Poka-Yoke devices. Most disturbances caused by unplanned machine downtime will be eliminated through implementation of Lean principles. We will create an accurate flow of information by eliminating the forecaster. Since forecasting is essentially guesswork, the optimal value for the forecasting factor is ‘0’. In this case, the required quantity will be passed directly to the supplier.

Products must be “pulled” by the shipper which will serve as the signal to begin production rather than “pushing” an order for a given quantity of goods through the factory. The shipper will “pull” or remove product to fill a shipment at a rate which will fill the day’s demand from the customer. The length of time between productions of successive parts to meet a demand is called the Takt time. We must establish a preset or refined inventory quantity which will replace the inventory controller by creating a flow of information which flows in the opposite direction of the material flow and sets the total quantity of parts that can be in inventory at any given time. In essence we are specifying a fixed and controlled quantity of inventory, rather than allowing it to fluctuate as was the case in the traditional manufacturing system. Having a fixed quantity of inventory in the factory will eliminate the amplification due to variability in customer demand. Incoming orders are now received by the shipper who begins removing finished goods from the shipping area at a rate equal to the Takt time. The Takt time is the rate at which the shipper must pull a single part in order to fill the order for the day. The factory in turn pulls raw material from the raw material bins and
produces parts at the rate that the shipper is pulling finished goods. Finally, the material planner multiplies the Takt time by the reorder quantity and determines the frequency that shipments must be received from the supplier. This system is considerably simpler. Information transfer in the form of the shipper removing product now forms the feedback for the control loop. The factory is not instructed to produce a certain quantity of goods, but rather to produce at a certain rate, as they are pulled to be shipped. By reversing the flow of information, we have transformed a system which “pushes” orders through the factory into a system in which a “pull” of product by the shipper (at a frequency set by the Takt time) signals the system to begin production.

### 1.3.4 Flexible Manufacturing Systems

Flexible manufacturing systems (FMS) are distinguished by the use of computer control in place of the hard automation usually found in transfer lines. The high investment required for a FMS and the potential of FMS as a strategic competitive tool make it attractive to engage in manufacturing research area. Articles emphasizing many methodological perspectives are critically reviewed from multiple viewpoints. FMS are distinguished by the use of computer control in place of the hard automation usually found in transfer lines. This enables FMS's to reconfigure very rapidly to produce multiple part types. Use of fixtures and tool magazines practically eliminates setup time. These features permit economic production of a large variety of parts in low volumes. FMS's are increasingly being adopted in the manufacturing sector on account of the additional advantages of rapid turnaround, high quality, low inventory costs, and low labour costs. The high investment required for a FMS and the potential of FMS as a strategic competitive tool make it attractive to engage in research areas. The research problems raised by the industrial support of FMS could be broadly classified into two areas: design problems and operation problems. At the design stage,
one is interested in specifying the system so that the desired performance goals are achieved. The operation problems are aimed at making decisions related to the planning, scheduling, and control of a given FMS.

1.3.5 Nagare Cell Manufacturing

Nagare cell is a Japanese concept based on single product flow and the U shaped layout of the cells in which the operators walk around the cell performing various actions including material handling from raw materials to the finished goods. Nagare Cell is a natural group of machines, men and parts manufactured in it, where men move from machine to machine carrying work piece with them. Nagare cell manufacturing (NCM) is a series of techniques for identifying and eliminating inventory by continuously improving the flow of product at the pull of the customers has been pointed out by Brooks and Duffill (1992). This system satisfies the customers on delivery, quality and price. The basic goal is to get more work done with fewer resources and results in dramatic reduction of cycle times, faster customer responsiveness, increased employee productivity and higher equipment utilization. Space requirements, scrap and rework are also reduced. In addition Nagare cell is also a Just in time manufacturing approach used to achieve the excellence in a manufacturing based on the continuous elimination of waste and consistent improvement in productivity. It provides the cost of effective production and delivery of only the necessary quality parts, in the right quantity at the right time.

1.4 JUST IN TIME

JIT is an action program to continuously and simultaneously work towards excellence in manufacturing by eliminating waste. Dimensions of excellence are
- zero defects
- zero customer lead time
- zero inventory
- zero down time.

The dimension of waste is anything other than the minimum amount of resource which is absolutely essential to add value to the product. Resources include materials, space, labour (works, staff and executive), cash, cit, machines and energy. Simplification of the enterprise objectives can help us to make the choice

- To make money
- With excellence
- By eliminate waste

Significant small changes can be started with a low-cost option of welfare: a cleaner factory, better tool storage, revised plant layout, shorter lead time, reducing inventory levels, cutting lead times, reducing batch size to customers’ needs has increased efficiency of production. The workforce for providing product quality and adopting a more responsive attitude to the customer are all now paramount. This has only been achieved by communication, technical ability and commitment from its entire workforce, aided by externally driven training programs. The need to compete on all these fronts without major capital outlay has shown improved company performance over consecutive years, with the ability to stay ahead of competition. The introduction of new manufacturing practice has improved output and quality; the respective cell managers are now directly responsible for customer targets within agreed budget guidelines. This has encouraged flexible working by its operatives. From a managerial point of view, the ability to accept change is a priority. The examination of the present
performance by the competitors can identify strengths and weaknesses for attention. Marketing, manufacturing and ongoing training reconcile the needs of customers, employees and the firm.

1.5 SEQUENCING AND SCHEDULING

Sequencing is a technique to order the jobs in a particular sequence. There are different types of sequencing which are followed in industries such as first in first out basis, priority basis, job size basis and processing time basis etc. In processing time basis sequencing for different sequence, will achieve different processing time. The sequence is adapted which gives minimum processing time. By Scheduling, one can assign a particular time for completing a particular job. The main objective of scheduling is to arrive at a position of getting minimum processing time. Pinedo (2005) demonstrated the information flow for a manufacturing system is shown in Figure 1.5. In a manufacturing environment, the scheduling function has to interact with other decision making functions. After a schedule has been generated it is necessary that all raw materials and resources are available at the specified times.
1.5.1 Types of Scheduling

The processing of n jobs with m operations on each of the machine is flow shop scheduling. Basically there are three types of scheduling, they are
- Single Machine Scheduling - The processing of n jobs with the same single operation on each of the jobs is called as single machine scheduling.

- Flow Shop Scheduling – There are n jobs, each requires processing on m different machines. The order in which the machines are required to process a job is called process sequence. This type of scheduling is flow shop scheduling.

- Job Shop Scheduling – Each job has m different operations, if some of the jobs are having less than m operations, the required number of dummy operations with zero process times are assumed.

This Venn diagram can show the relative sizes between different types of schedules as shown in the Figure 1.6 there will be at least one optimal schedule in the set of active schedules.

![Venn diagram showing different schedules](image)

**Figure 1.6** Venn diagram showing different schedules
1.5.2 Combinatorial Scheduling Techniques

It is known that the decision making associated with the scheduling problem belongs to the category of combinatorial optimization problems. The range of techniques that have been applied to tackle combinatorial optimization problems can be classified in two general categories, firstly, the exact methods and secondly the approximate (heuristic) methods. Exact methods seek to solve a problem to guaranteed optimality but their execution on large real-world problems usually requires too much computation time. Consequently, resolution by exact methods is not realistic for large problems, justifying the use of powerful heuristic and metaheuristics methods. The detailed classification of different methods has been shown in Figure 1.7 and 1.8.

![Figure 1.7 Classification of common search methodologies](image-url)
1.5.3 Plant Layout

Layout pattern determines the placement of departments, work groups within the departments, workstations, machines, and stock-holding points within a production facility are very important for effective working environment. The objective is to arrange the various departments in a way that ensures a smooth work flow (in a factory) or a particular traffic pattern (in a service organization). In general, the inputs to the layout decision are as follows,

1. Specification of the objectives and corresponding criteria to be used to evaluate the design, the amount of space required, and the distance be traveled between elements in the layout, are common the basic criteria.
2. The estimate of product or service demand for the system.

3. The processing requirements in terms of number of operations and amount of flow between the elements in the layout.

4. The space requirements for the elements in the layout.

5. The space availability within the facility itself, or if this is a new facility, possible building configurations.

The emphasis is on quantitative techniques, but also with examples of how qualitative factors are important in the design of the layout for both manufacturing and service facilities.

**1.5.4 Layout Formats**

The formats by which departments are arranged in a facility are defined by three basic types (process layout, product layout, and fixed-position layout) and one hybrid type (group technology or cellular layout).

i) A **process layout** (also called a job-shop or functional layout) is a format in which similar equipment or functions are grouped together, such as all lathes in one area and all stamping machines in another. A part being worked on then travels, according to the established sequence of operations, from area to area, where the proper machines are located for each operation. This type of layout is typical of hospitals, for example, where areas are dedicated to particular types of medical care, such as maternity wards and intensive care units.

ii) A **product layout** (also called a flow-shop layout) is one in which equipment or work processes are arranged according to
the progressive steps by which the product is made. The path for each part is, in effect, a straight line. Production lines for shoes, chemical plants, and car washes are all product layouts.

iii) In a **fixed-position layout**, the product (by virtue of its bulk or weight) remains at one location. Manufacturing equipment is moved to the product rather than vice versa. Construction sites and movie lots are examples of this format. Many manufacturing facilities present a combination of two layout types. For example, a given production area may be laid out by process, while another area may be laid out by product. It is also common to find an entire plant arranged according to product layout for example, a parts fabrication area followed by a subassembly area, with a final assembly area at the end of the process. Different types of layouts may be used in each area, with a process layout used in fabrication, group technology in subassembly, and a product layout used in final assembly.

iv) A **group technology (cellular) layout** groups dissimilar machines into work centers (or cells) to work on products that have similar shapes and processing requirements. A GT layout is similar to a process layout in that cells are designed to perform a specific set of processes, and it is similar to a product layout in that the cells are dedicated to a limited range of products. (Group technology also refers to the parts classification and coding system used to specify machine types that go into a cell.)

v) **U shaped cell** the most sensible organizing cell layout preferable for effective utilization is a “U” shaped layout.
This is product flow oriented and operators become capable of handling multiple processes. Also enable operators to produce and transfer parts (single piece at a time). It minimizes the operators walking time and walking distances. It rectifies the additional space required to accumulate the in process inventory, unnecessary handling of materials, slow feedback of quality information and longer production lead time.

1.6 SIMULATION

One of the gurus of simulation so called Robert E. Shannon (1975) historically defined simulation as “the process of designing a model for a real or imaginary system and conducting experiments with that model for the purpose of either understanding the behavior of the system or for evaluating various strategies (within the limits imposed by a criterion or set of criteria) for the operation of the system.” This primitive definition highlights the general framework of simulation principles and gives a clue of the roadmap that simulation has gone through within the last century. Each and every word can phrase the definition emphasized the exact comprehension of the term simulation. The first sentence of the definition mentions the types of systems that simulation studies can be conducted on. The systems can be “real” or “imaginary”, which means that there can exist a physical facility or a process to be modeled, or the model can be a modification of the existing system or it can be totally imaginary. The imaginary systems refer to the ones that are planned as alternatives to existing systems or for entirely the original systems.

1.6.1 Simulation Process

Simulation is a continuous “process” rather than a onetime create-and-use application. Especially computer simulation is an iterative method that includes several stages has been identified by Kelton et al (2004). A
simulation study starts with efforts on understanding the system in addition with the identification of the goals of the study. Then create the formulation of the represented model usually in terms of mathematical models or flowcharts. Subsequently, the created formulation needs to be transfer into modeling software using programming languages or with specific software tailored into the needs of a simulation study. Once a program is created, it is necessary to verify the program, in the sense that the right things occur with expected inputs. The following stage is to validate the program with someone familiar to the represented system so that the program works in accordance with the conceptual model faithfully, supporting the validation work with statistical tests can be of critical importance at this stage. Experimentation on the developed model is the following phase, which includes designing experiments to identify the critical performance measures to be used with adequate confidence and running these designed experiments by using the computers effectively. The last stages take account of analyzing the results, getting insight of the results to evaluate the outcomes of the results and to assess the potential benefits. Finally, documentation is necessary for the inheritance of the work done for other simulation staff and also to clearly transfer the findings and recommendations to related management levels with precision and confidence.

The life cycle to be followed during simulation study has been identified in detail by Osman Balci (1990) for 10 processes, 10 phases and 13 assessment stages. Figure 1.9 provides the details of identifications and the precedence & succession relations between them.
All those steps mentioned in the Figure 1.9 seems troublesome and time consuming, however success in simulation is difficult to attain without following these steps. It is necessary to identify what success is at this stage. According to Sadowski (1997), a successful simulation project is the one that delivers useful information at the appropriate time to support a meaningful decision, which implies that decision, timing and information are the three key elements to be assessed to get success in simulation.
1.6.2 **Simulation Benefits**

Simulation has many benefits for the users. First of all, the users can choose correctly the possible alternatives, provides time compression and expansion according to the type of the simulated event, equips the managers with the tools to understand certain phenomena occur in a real system and allows the user to explore possibilities of new policies, operating procedures or methods. With simulation, one can diagnose problems of complex systems that are almost impossible to deal within the real environment, identify constraints that act as a bottleneck for operations, visualize the plan using the animation capabilities of the software used that results in a more presentable design. Simulation is also beneficial to build consensus among the members of the decision makers and to prepare for changes by considering the possible “what if” scenarios. Virtual reality support creates training environments for production team, it can also be used to specify requirements for capabilities of equipment and carry out wise investments using all those properties. In accordance with this definition and benefits, simulation has been extensively used as an off-line decision making tool for helping the management with production planning issues such as efficient capacity utilization, sequencing and scheduling and allocation of resources in manufacturing and production.

1.7 **RESEARCH OBJECTIVES**

A new scheduling and simulation strategy to address the problem statement i.e. the objectives of this research are summarized as follows

1. To develop a design methodology for NCM systems in dynamic and stochastic production environments which employ system reconfigurations and routing flexibility?
2. To justify the NCM design methodology via experimental problems and compare with known solutions.

3. To identify the optimal schedule by SPT algorithm and simulating the model.

1.8 RESEARCH APPROACH

To achieve the development of NCM design methodology, the research approach consists of the following steps

1. Designing a NCM problem for dynamic production requirements.

2. Evaluate the potential benefits gained through the consideration of system dependent reconfiguration and routing flexibility.

3. Generate problem instances to be used for validating the developed design. Incorporate uncertain production requirements into the developed design.

4. Develop and validate a heuristic approach for dynamic and uncertain production requirements due to the computational time required for large problems.

5. Evaluating experimental design to compare performance of heuristic versus optimal and vs. other heuristics.

6. Developing the logic for simulation and run the simulation by packages.

7. Discussing the results and the output of the problems solved.
8. Summarize the conclusions and discussing the directions for future work.

1.9 OUTLINE OF THESIS

This dissertation or the progress work is organized as follows. Chapter 2 presents the previous literature reviews which helps in defining and solving the design of Cellular manufacturing system, its scheduling phase and its simulation phase of this work. Chapter 3 contains the problem statement of this thesis. Chapter 4 covers the manufacturing evolution since from 1980’s i.e. Cellular manufacturing to Nagare cell. Chapter 5 covers the CM layout and its advantages. Chapter 6 explains the first phase of the work i.e Nagare Cell Manufacturing i.e. design & its evaluation phase. In Chapter 7 the methods used for scheduling NCM and evaluation methodology with new modified algorithm heuristic is presented. Chapter 8 presents the NCM simulation and the methods applied in this work with the results from the evaluation. Finally Chapter 9 gives conclusions, contributions, and the future research of this work.