CHAPTER 6

NAGARE CELL MANUFACTURING

6.1 INTRODUCTION

The concept of Nagare Cell Manufacturing system and its design principles with experimental case study is discussed in this chapter.

6.1.1 Continuous Quality Improvement

Every company is having strategy to work towards world class standards of performance in terms of costs, quality, lead times, stock levels, and responsiveness for changing customer requirements. Some of the factories laid and managed in separate process-based departments, although the process route for the main product had cellular features. So industries are aware of the competitive benefits attributed to cellular organization.

6.2 NAGARE CONCEPT

The one that each organization likes the most about the future for manufacturing is futuristic design and can make it happen. Now let’s see about Nagare concept the word itself pronounced as “na-ga-reh”, the first series of design concepts in manufacturing. Nagare was born; with the meaning of flowing (in Japanese) this design achieves the goal of fresh design for competitive manufacturing field. To fully understand the potential of this modern technology, manufacturing engineers travelled to the Makino NCMT grinding division at Coventry to witness some of the technology in action.
The most usual production process for this popular aerospace component is in a Nagare cell comprising, say, 10 separate machines tended by five operators to clamp every part once on each machine. On a Makino VIPER machining centre, parts generally come off complete in two operations, drastically reducing production costs. This forms part of the repeating products cell in a ‘U’ shaped, one piece at a time, machine group layout called Nagare cell (NC). The need for this arose from a major order for two or more new products, which were complex stampings needing extensive precision machining. The solution adopted was to create a dedicated group of conventional machines, all but one of which was already available on the shop floor. Output is flexible, with between one and four operators working simultaneously. The benefits gained include low capital expenditure, very high labour productivity, minimal work in progress, and short lead time. Further the detailed information about the design and operation of the Nagare cell is given in this section.

6.2.1 U Shaped Layout

In the just-in-time context, parts are often processed by a single-unit production system called “Nagare Cell” without conveyors. The U-shaped layout, in which each worker takes charge of several machines, has been introduced as an implementation of this concept. Presently the layout is gaining an increasing popularity due to the low running cost. In this section, first the U-shaped production line with a single multi-function worker is dealt then his waiting time, cycle time of the line processing times of items, operation times, and his walking times between machines are also dealt. Then the same with a U-shaped production line with multiple workers, derivation of overall cycle time of this line, and optimal worker allocation is given. In particular, it is understood that the U-shaped layout is superior to the linear
layout for lines with one or two workers. The U-shaped production line with three workers and six machines is shown in Figure 6.1.

![U-shaped layout diagram](image)

**Figure 6.1 “U” shaped layout**

Therefore, when the demand changes one can more appropriately reallocate the workers to machines so that the cycle times of workers are balanced. That is, the U-shaped layout can be more properly adapted to the changes of the circumstances than the linear layout. The overall cycle time of the U-shaped line with more than one multi-function worker, which is the maximum of the cycle times of all workers. It is noted that its reciprocal gives the throughput, or the production rate of finished products. Particularly, Miltenberg and Wijngaard (1994) considered the line balancing problem of the U-shaped line with constant operation times, no waiting times and no walking times. They discussed the optimal machine allocation problem to workers (which they called stations) under the constraints on the orders of
To further reduce an overall cycle time by admitting what Toyota calls mutual relief movement stated by Monden (1993). This means that a worker who has finished his own operations in one cycle helps another adjacent worker. This, however, is not taken into account in this work because the problem becomes more complicated. If multiple kinds of items are processed in this line, the processing times and operation times are not constant. In addition, the operation and walking times of the worker may fluctuate because of his weariness and learning effect.

### 6.2.2 Cycle Time and Waiting Time

This section explains the U-shaped production line with a single multi-function worker, which is shown in Figure 6.2. The worker handles machines 1 through K. The facility has enough raw materials in front of machine 1. The material is processed at machines 1, 2, ..., K, sequentially, and departs from the system as a finished product. Let $K = \{l, \ldots, K\}$. When the worker arrives at machine $k$, if the processing of the preceding item is completed, then he removes it from machine $k$, sends it to machine $k + 1$, 

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**Figure 6.2 A U-shaped Production Line**
attaches the present item to machine k and switches it on. After the operation at machine $k$, he walks to machine $k + 1$. If the preceding item is still in process at his arrival, then he waits for the end of the processing before the operation.

If the worker does not wait at any machine then the cycle time is simply the sum of all operation and walking times. Since one item is processed and operated at each machine in one cycle, the cycle time must be greater than or equal to the maximum of the sums of the processing and operation times among all the machines. If the worker starts from the machine with the maximum sum, then the cycle time will be equal to the maximum of the maximum sum and the sum of all operation and walking times.

6.3 NAGARE CELL MANUFACTURING

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 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 formulated by Brooks (1994). 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 and at right place.
6.3.1 NCM Principles

The basic NCM principles are, NC can be designed and implemented for product flow system. NC helps to fulfill the customer demand per day, Minimize production instability by preventing demand fluctuations from one process to another, Provide better control through decentralized shop floor control, improvement in the rate of production from bottleneck machine will increase installed capacity of the cell. This could shift bottleneck to some other machine. In turn improvement efforts can be directed at the new bottleneck machine. Beyond the maximum level of improvement, addition of more number of bottleneck machines will increase installed capacity. Non bottleneck machines will inevitably have idle capacity.

6.3.2 NCM Objectives

- Fulfilling customer demand per day
- Minimize work-in-process inventory
- Minimize fluctuations in WIP to simplify inventory controls
- Minimize production instability by preventing demand fluctuations from one process to another.
- Provide better control through decentralized shop floor control.
- Reduce defects.
- Better quality products
- High inventory turnover
- Higher productivity
- Lower production costs.

6.3.3 NG Taxonomy

a) Operation

Operators walk around the Cell. Machines are loaded manually and often unloaded automatically. Machines work on auto cycle, wherever possible, while the operator moves on to attend to subsequent machines. Operators are fully occupied. Machines are utilized to the extent of the requirement of market demand.

b) Flow

Machines are arranged in the sequence of operations. Materials flow smoothly through the multi-process Cells. Parts are carried manually from machine to machine by operators.

c) Cycle Time & Installed Capacity

Cycle time is governed by the slowest that is the bottleneck machine. This decides the installed capacity of the Cell. Capacity can be increased by adding more of bottleneck machines and rearranging the Cell.
d) **Output & Manning**

Within the installed capacity, the output is decided by the number of operators in the Cell. Manning strength is decided on the basis of required output rate. Output can be increased up to the installed capacity by adding more operators.

e) **Machine Design**

Machines are preferably simple, narrow with all operator controls and adjustments in the front, maintenance approach from the rear, push button auto-cycle with manual loading/auto unloading, quick change over, reliable operation, proper process capability and with mistake proofing (POKA YOKE).

f) **Quality**

High quality built in with proper process capability of machines, mistake proofing, trained operators doing necessary quality checks before proceeding with subsequent operations, enabled/empowered/motivated teamwork

g) **Production And Transfer Batch Size**

Production batch size minimized due to quick change-over, short manufacturing lead time, better quality and system reliability leading to the practice of make daily sell daily. Transfer batch size reduced to one leading to single piece transfer.

h) **Lower Capital Expenditure**

Simple and less expensive machines reduce capital expenditure
i) **Flexibility And Responsiveness**

Increased market demand can be met easily, by adding more operators in the Cell. Simple machines enable quicker change over. Cell capacity can be increased by adding more of bottleneck machines and rearranging the Cell.

j) **Skill Requirement**

Simple machines require lower level of skill in machine operation, setting and maintenance. Essential training enhances the ability of the team manning the Cell and reduces dependence on outside experts.

k) **Stock Reduction**


6.3.4 **NCM – Pre Requisites**

- Machines must be process capable
- Nagare Cell ensures quality through the system. Cell cannot work uninterrupted if even one machine suffers lack of process capability.
- Machines should have short cycle time
- Long cycle machines are unsuitable for Nagare. At the same time too short a cycle time will now allow time for operators to move around and work on other machines.
- Machines should not be very expensive

- There are inevitable idle times on non bottleneck machines in a Cell working to capacity and all machines in a Cell working less than capacity.

- Operators must be capable of operating all machines in a Cell

- Normally operators will operate more than one machine. If demand falls, fewer operators will be necessary, each working on even more number of machines. Hence, each operator capable of working on every machine in a Cell is an essential requirement.

- Machines should have Auto-Cycle

- If one or two exceptions are there, Nagare Cell still works.

- Machines should be reliable

- Operators should be trained in TPM and be capable of cleaning, lubricating and simple maintenance.

The design stages of NCM are shown like a flow chart in the Figure 6.5.
(i) **Stage 1 - Identify component families**

A suitable family would have the following characteristics. All components require the same operations (or a sub-set) in the same sequence. All components have similar physical characteristics (to enable the use of common fixtures) components are suitable for manual handling or simple transfer devices medium to high volume, low variety components do not have tight positional tolerances between dissimilar features (this could require complex fixtures). There are many techniques available for identifying machine and component groupings. These include product flow analysis, rank order clustering and graph analysis techniques. These techniques will help to identify components that use the same set of machines. However, they do not take into account the operations performed by the machines or the order in which the operations are performed. The techniques can yield results quite quickly providing a useful ‘filtering’ function. The rough groups identified can then be analyzed in greater detail. Component drawings can be analyzed to determine the degree of physical similarity - perhaps using a simple classification technique. Attention should be paid to total variety and dimensional differences between varieties. This may affect tool design for
quick but positive changeovers. Stage 1 is best carried out as a team exercise involving production engineers from the Factory or product unit. In complex cases manufacturing systems engineers may be needed to assist in the analysis.

(ii) **Stage 2 - Process design**

Once a suitable component family has been identified, a list detailing all operations required for each component is compiled. This list will not simply be the same as the route card as several operations may be combined at one machining centre. Every operation including manual and inspections must be listed. All operations must be studied and their necessity questioned. All unnecessary operations must be eliminated.

This may require design changes and so liaison with the component designers will be essential. It may also be possible to identify changes that will enable the component to be manufactured more easily.

It has to check some information required, they are outline the size, shape and weight, robustness to handling, finished component drawings, stage drawings if they exist, critical dimensions or key quality features, existing process layouts - map from and to sequence machines - network diagram, existing cutting tool details component material, operations details per machine including cycle time and set up time, existing machine details - speed and feeds - effectiveness - tool and fixture drawings, cycle control details - plan and elevation drawings - arrangement drawings Existing gauging or quality control details, dimensional tolerance required - general level
(iii) **Stage 3 - Design line layout**

The objective of this stage is to determine the sequence of operations that will result in a balanced line with material flowing in one direction only. A starting point will be the calculation of the required line cycle time, this is the time between successive components coming off the line. The required cycle time is determined by the customer demand rate and the actual time available. It is very important at this stage to make realistic allowances for all sources of non-operating time eg. Preventive maintenance, cleaning, operator absence for meetings or natural breaks, scrap, breakdowns, setup times etc.

A design for manufacture could help to reduce, simplify or combine manufacturing operations. Any operation that has an operating time (machine element + manual element) greater than the demand cycle time requires immediate attention. If the operating time is only marginally greater than the cycle time then it may be possible to reduce the operating time by a rigorous method analysis. If this is not sufficient then it may be necessary to duplicate the machine performing the operation. The list of operations should be examined to determine if any can be combined and performed at one machine. The output from this stage will be a list detailing the number of machines or stations required the operations to be performed at each station (manual and machine operations), the sequence of operations and an estimate of operating times. This stage may involve selecting the best from more than one possible configuration. Necessary examination of machine design and cost should be applied to all options to determine the best.

(iv) **Stage 4 - Machine selection & Design**

Using the information from the previous stage, the machines, tools and fixtures can now be designed or modified from existing equipment. The
machines would, ideally, be designed specifically for the operations identified from the previous stage observing the following guidelines.

- Very simple machines designed to optimize tool life and reliability.
- The machines should be capable of auto-cycling, auto unloading and automatic fixture cleaning.
- Machines should be narrow to minimize the distance walked by the operator.
- The machines should be designed for ease of maintenance.
- Machines should be able to detect abnormal conditions and stop automatically.
- Work holding fixtures should be very simple and incorporating mistake-proofing devices (Poka Yoke).
- Appropriate quality control methods need to be included.
- If gauging facilities are included, they should be designed in the same way as the machines.
- Machine Systems redesign should be used.

(iv) **Stage 5 - Design operating procedures**

- Before developing the operating procedures, the number of operators must first be determined. To do this you simply add up all the manual operating times plus the time required walking from machine to machine. This is effectively the time that it would take one operator to complete the whole loop.
The number of operators can be found by

\[
\text{Number of Operators} = \frac{\text{Total Manual Content}}{\text{Demand Cycle Time}}
\]

A Standard Nagare worksheet can be extremely useful.

A standard work chart as shown in Figure 6.6 would be drawn up for all components in the cell.

Operating instructions should be detailed for all machines or stations.

(vi) Stage 6 - Simulation

The last stage is to simulate the operation of the line under normal operating conditions. Due to the simplicity of the line hand simulation techniques should be adequate, otherwise ARENA can be used. An application of failure mode and effects analysis at this stage will help to pin-point any weakness in the proposed design.
6.4. NCM - CHECKLIST DELIVERABLES

Depending on the nature of the customer requirements and follow up work, some or all of the following deliverables will be required:

- Nagare standard worksheet
- Process planning details per part (factory standard sheet)
- Operator Instructions
- Quality control charts

Operator preventive maintenance procedures, cell layout drawing to scale written specifications for machine, modifications and quality control equipment, outline drawings of any tools, fixtures, and gauges, either new or modified. Operator training material component stage drawings should be clearly educated to the workers.

For example a product has to be produced in production batch of 1000 means the transfer batch diagrams as shown in Figure 6.7 can be easily made by NCM technique should help how that can be processed. A model transfer batch diagram for making a single part with 5 operations is shown in Figure 6.8. It shows that for a production batch and transfer batch of 1000 pieces, with 5 different operations, it takes 15000 minutes, i.e. for turning 2000 minutes, milling 4000 minutes, drilling 3000 minutes, induction hardening
1000 minutes and finally grinding 5000 minutes. Therefore 1000 pieces of finished part can be completed in 15000 minutes.

The Figure 6.9 shows the transfer batch diagram for a part group transfer. Here 1000 pieces of A, 600 pieces of B and 400 pieces of C will be completed in 10000 minutes. So by transferring the part in group, three parts will be completed at the end of the process. Some improvement is noticed by minimizing the transfer batch from 1000 to 500 pieces. Minimum one set of 500 pieces of A, 300 pieces of B and 200 pieces of C will be completed within 5000 minutes. It shows that by changing the transfer batch from single part to part group the jobs can be finished within short period of time.

Figure 6.8 Transfer batch diagram (single part)

Figure 6.9 Transfer batch diagram (Part group)

Smaller batch size results in good reduction not only of throughput time, but also lead time, and planning cycle. Shorter lead time and planning cycle enables more accurate demand scheduling and avoiding change in
demand schedule within the current planning cycle. This in turn results in uninterrupted production as per plan and therefore 100% schedule adherence was achieved. Batch size reduction results in more frequent change-over settings. This in turn results in larger loss of available production time, due to change-over setting.

6.5 NCM – A HEURISTIC APPROACH

This sub section focuses on the development of a NC design as briefly defined by Brooks (1994) an evolutionary path from an early rough cut version to full perfection via continuous improvement to meet out the customer demand per day. This section attempts to bring out man, machine and materials in to a product with the aim of eliminating the intercellular moves and maximizing the operator efficiency. It proposes a new product flow NC design for manufacturing in an operating flow shop. By applying NC principles to produce parts with similar manufacturing processes and stable demand, industry can expects to reduce costs and lead-times and improve profits, quality and delivery performance. Here it outlines a method of formulating principles, designing, and implementing the NC, the conclusions of the paper highlights the reduced defects, Better quality products, High inventory turnover, Higher productivity, Lower production costs uce the manufacturing cycle time, material handling time and inventory and at the same time increase the output of the operators.

The most sensible organizing cell layout preferable for NC is a U shaped layout explained by Cao and Chen (2005). This is product flow oriented and operators become capable of handling multiple processes as given in Figure 6.10. Also enable operators to produce and transfer parts (single piece at a time). It Minimize 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.
Assessment of Flow Product Shop

Understanding the nature of the product, life cycle is very useful in determining the appropriate production strategy. Several flow product systems showed that the typical production is characterized by batch-oriented processes, large monument-like equipment that cannot be relocated into cells, a large variety of products being produced at any time in the facility and manual shop floor communications between machine operators, forklift drivers and plant managers/supervisors proposed by Mansouri (2000). This dispersion of the manufacturing assets and the functional layout of the facility at each location, results in a value added Ratio of about 10%. Products that have a high unit price are seen to have the highest lead times in both dimensions, which is the primary reason for high WIP costs. However, it must be recognized that the typical manufacturer operates in a make-to-order business environment. These flow shop-type manufacturers do not have an extensive suite of well-documented, easy-to-use and thoroughly validated methods and tools to support their implementation of NCM. Clearly, there is a need for new concepts and analysis tools specifically suited for flow product system to implement NCM in a manner that suits their business model and manufacturing environments. The following section explains about the design procedure of NCM system and implementation strategies to be considered for a new product with some basic assumptions to be assumed for making this system very active.
6.5.2 NCM - Design Phase

The NCM design phase consists of ideal starting point which would be early in the product design cycle so that the product and the manufacturing system could be designed simultaneously has been stated by Tiente et al (2008). The design procedures can be illustrated by 6 main stages which are,

Stage 1. Identify component families
Stage 2. Process design
Stage 3. Design line layout
Stage 4. Machine selection and design
Stage 5. Design operating procedures
Stage 6. Simulate and verify the design

6.5.2.1 Basic assumptions

1. Machines should be are arranged based on product flow (‘U’ shaped layout )
2. Operators should walk around the cell
3. Machines can be loaded manually and unloaded automatically
4. Tools and support materials have a pre-determined place and are maintained tidily
5. The cell layout manning pattern changes with change in customer demand
6. The manpower is planned for maximum utilization
6.5.3 Exhibit

A case study was made in a leading diaphragm manufacturing company and its data’s were used for the design of NCM strategy over there. In rubber moulding section 30 different products were processed in moulding machine of various processing stages. Among those 30 some 5 different part family grouping problems are considered as the exhibit study in the following sections. They are designed based on the principles of design for flow to achieve waste-free, and therefore high-velocity, flow of orders without necessitating repeated shop floor reconfiguration. Skilled operators are required and they must get trained in TPM and be capable of cleaning, lubricating and do simple maintenance. Say for an example a product of 3 different parts has to be completed by eight continuous processes with the following processing time as given in Table 6.1, the NCM design phase can give out solution.

Table 6.1 Processing time

<table>
<thead>
<tr>
<th>Sl.no</th>
<th>Operation</th>
<th>Processing time (min/piece)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Process 1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Process 2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Process 3</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Process 4</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Process 5</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Process 6</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Process 7</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>Process 8</td>
<td>2</td>
</tr>
</tbody>
</table>

An exhibit of 1000 pieces has to be manufactured as customer demand per day. Assuming transfer batch size equal to the production batch size, throughput time for the batch of 1,000 pieces is 15,000 minutes plus all the transportation and waiting times at the beginning and end of each operation. This brings the machines in a product layout (U shaped layout).
The first piece is complete in 15 minutes. Thereafter for each cycle one piece will be ready by every 6 minutes by continuous flow and application of NCM principle. The NVA chart in figure 6.11 shows the throughput time for the batch of 1000 pieces as 3012 minutes only. A sharp reduction takes place from 15000 minutes to 3012 minutes by NCM strategy. Again if the transfer batch is reduced as 500 from 1000 it is taking 2515 minutes only for complete cycle. It is noticed that by reducing the transfer batch the throughput time is reducing.

![Figure 6.11 NVA Chart](image)

### 6.5.3.1 Standard Nagare Work Sheet

A standard Nagare work sheet is shown in Figure 6.12. It is a manually prepared chart which gives the details about part machining time, machine idle time & part idle time and number of operators required. A thin vertical line represents the time required for the product transfer from one machine to another machine. A wavy line is drawn to show the idle time of the machine and operator walking time from one machine to the next. In addition, from the work sheet the operators can easily know their level of working status. The worksheet shows that three parts, for example A, B & C can be machined in a group. By starting the machining of part A then B and C,
one set of part B will be completed first in 9 minutes with 0 minutes machine idle time, then A will be completed secondly in 11 minutes with 1 minute machine idle time and C will be completed in 16 minutes with 3 minutes machine idle time. Then second set of part B in 9 minutes with 1 minute idle time, A in 7 minutes with 6 minutes machine idle time and C in 6 minutes with 6 minutes machine idle time and likewise the entire schedule will be completed.

![Figure 6.12 Standard Nagare work sheet](image)

6.5.3.2 Numerical calculations

Let the customer demand per day is 1000 (A+B+C) pieces.

Determination of Manufacturing Cycle Time:

a) Total operator cycle time.
   
   Manual operation = 120 Seconds / piece.
   
   Total operator cycle time = manual operation + total walking time
   = 150 Seconds/piece (or) 150000 seconds.
b) Total machine cycle time (MCT)

Machining time (MT) = 960 seconds/piece

Machine cycle time (MCT) = MT + loading or unloading time
= 180720 seconds

Total machine cycle time = machine cycle time + allowance time
= 180720 + 1800 seconds
= 182520 seconds

c) Manufacturing cycle time = Max (total operator cycle time, Machine cycle time)
= 182520 seconds. ie 182.52/piece

Available time per shift = 7 hours 30 min (excluding tea and lunch)
= 27000 seconds

d) Total no of shifts required = \[
\frac{\text{Manufacturing cycle time}}{\text{Available time per shift}}
\]
= 24336 seconds (6.76 shifts)

e) Takt time = \[
\frac{\text{Total shifts required to complete}}{\text{Available shifts per day}}
\]
= 2.25 shifts (60750 seconds)

Therefore one operator has to work for 2.25 shifts.

f) No of operators required = \[
\frac{\text{Manufacturing cycle time}}{\text{TAKT time}}
\]
= 3 Operators

Therefore 3 no of operators are required.
6.5.3.3 Results

For manufacturing the product of A, B and C, 1000 pieces requires,

- 3 no of operators
- 2.25 shifts for an operator
- 7.5 hours per shift.

6.6 COMPARATIVE ANALYSIS

A comparative analysis was made between CM layout and NCM layout as shown in Figure 6.13, by the implementation of NCM and its techniques; an astonishing impact is noticed on the product flow factory. Here are some of the measurable benefits accrued to the company. The implementation results show that; work-in-process inventory has been reduced from 40% to 10%. On-time delivery has been improved from 55% to 95%. Manufacturing cycle time has been reduced from five weeks to less than one week. Quality (based on customer demand) defects has reduced from 4% to 1.5%. Production efficiency has improved from 15 pieces to more than hundred pieces per manufacturing shift. Sales also increased by 30% percent because of on time delivery. The morale and attitude of the operators has improved.

![Figure 6.13 Comparative chart of NCM over CM](image-url)
6.7 CONCLUSION

This chapter concludes the U-shaped production line with one multi-function worker is considered, and his waiting time and the cycle time for the case where the processing, operation and walking times are constants were obtained. Then the overall cycle time of the U-shaped line with I multi-function workers, and formulated the optimal worker allocation to minimizes the overall cycle time by design principles the problem can be extended for I = 1 or 2 in the production line with K machines placed at the same distance were investigated and showed the advantages of the U-shaped layout over the linear layout. It is understand that the implementation of NCM concept is very much useful in meeting the customer demand per day, minimize WIP, minimize fluctuations in WIP to simplify inventory controls, minimize production instability be preventing demand fluctuations from one process to another, provide better control through decentralized shop floor control, reduce defects, better quality products, high inventory turnover, higher productivity, lower production costs are possible. The production schedules are met easily with minimum volume of product flow between the machines and useful for effective utilization of man power.

The above applied approach is only conventional design, but it can be extended to proper scheduling for getting optimal cycle time and exact number of workers. So the NCM scheduling procedure is discussed in chapter 6. In the future research we wish to investigate stochastic properties of the cycle time and the waiting time for the U-shaped production line in. An efficient algorithm to optimize worker allocation would also be desirable.