SPACE UTILIZATION IMPROVEMENT IN CNC MACHINING UNIT THROUGH LEAN LAYOUT

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Abstract

Lean is the term used to describe the production system developed by the Toyota company in the post World War II years. "Lean" comes from the ability to achieve more with less resource, by continuous elimination of waste. Ess Enn Auto CNC Private limited is a leading small scale company manufacturing precision machined components for the past 30 years in Bangalore. The enthused customers of Ess Enn Auto CNC have raised the production demand which could not be fulfilled with existing facilities. In order to continue serving increased customer needs, Ess Enn planned to acquire nine new machines additionally. The space constraint provided an opportunity to integrate lean techniques into the facility layout to accommodate all the new machines and to optimise the material movement with minimal investment.

The existing layout was modelled using AutoCAD, software. Product, processing, and resource data were collected to analyse current layout deliverable levels (space utilisation, material travel distance, material handling cost, etc.). Alternate layouts were generated using lean layout concepts such as 'group technology' and 'systematic layout planning', which facilitate relocating the equipment according to product processing. A suitable layout with efficient space utilisation and effective material handling was selected. This selected layout was validated and recommended for implementation.

The money saved in Unit-2 monthly rent and overall material movement optimization will lead to a savings of INR 6,72,828 per annum. The recommended layout will incur an estimated investment of INR 9,90,456 and the ROI will be 1.83 years. The new layout will free up half of the underground floor which can be used for future expansion. The flames of lean philosophy in Ess Enn have been fuelled by executing new layout, and this new layout will craft an opportunity to taste the other flavours of lean concepts such as 5S, Kanban, JIT, small lot production, etc.

Keywords: Lean Layout, Group Technology, Hybrid Layout, Systematic Layout Planning

Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
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<tr>
<td>ALDEP</td>
<td>Automated Layout Design Program</td>
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<td>CMS</td>
<td>Cellular Manufacturing System</td>
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<td>CORELAP</td>
<td>Computerised Relationship Layout Planning</td>
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<td>CRAFT</td>
<td>Computerised Relative Allocation Facilities Technique</td>
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<td>FLP</td>
<td>Facility Layout Problem</td>
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<td>GT</td>
<td>Group Technology</td>
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<td>HMS</td>
<td>Hybrid Manufacturing System</td>
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<td>JIT</td>
<td>Just in Time Systems</td>
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<td>Overall Equipment Effectiveness</td>
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<td>PFA</td>
<td>Product Flow Analysis</td>
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<td>SLP</td>
<td>Systematic Layout Planning</td>
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<td>TQM</td>
<td>Total Quality Management</td>
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<td>VBA</td>
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1. INTRODUCTION

The manufacturing industry accounts for a significant share of the industrial sector in developed and developing countries. The final products of an industry can serve either as finished goods for sale to end customers or as intermediate goods in the other production processes. The manufacturing industry has undergone dramatic changes due to significant and steady improvement in productivity. To remain globally competitive, the manufacturing industry fundamentally transformed itself through rapidly improving technology, implementation of lean manufacturing principles, multi-skilling, and innovative production process improvement techniques. Manufacturing industries are the chief wealth producing sectors of a nation’s economy. Although manufacturing now accounts for little over one fifth of total national output (GDP) and an even smaller share of total employment, many economists argue that the economic health of manufacturing has important implications for other industries. In the modern globalised economy, manufacturing organizations are faced with hard competitive situations. The global competition, characterised by the rapid technological innovations and ever-changing market demands, is putting enormous pressure on manufacturing organizations across the globe. The modern manufacturing organizations make an effort to achieve world-class performance through continuous improvement in the production systems and development of world-class products and services, to satisfy the strange and rapidly changing customer requirements. The challenges of hard competition and the drive for higher profits are forcing the organizations to implement various productivity improvement efforts to meet the challenges posed by ever-changing market demands.

India is fast emerging as a global manufacturing hub. India has all the requisite skills in product, process and capital engineering, thanks to its long manufacturing history and higher education system. India's cheap, skilled manpower is attracting a number of companies, spanning over diverse activities, making India a global manufacturing powerhouse. India with its vast design skills has attracted a lot of outsourcing technological orders. India's manufacturing sector is on an uptrend with the majority of sectors recording positive trends in the first half of fiscal year 2009-10, as compared with the corresponding period in 2008-09, according to a Confederation of Indian Industry (CII).
survey. The buoyant manufacturing growth in the first half is led by a rise in production of basic goods, intermediate goods and consumer durables [1].

Small Scale Industries (SSI) in India facilitates the tapping of resources for productive purposes with minimum amount of capital investment, which in turn helps to strengthen the industrial structure of a nation. SSIs have existed in India for a long time in various sectors and have contributed significantly in bringing down regional imbalance; generating employment opportunities, output, and exports; fostering entrepreneurship; in accelerating economic development. They occupy a position of prominence in India and contribute over 50% of the industrial production in terms of value-addition. This sector plays a key role in the industrialisation process and accounts for one-third of exports, and employs the largest manpower next to agriculture. The process of liberalisation, privatisation and globalisation (LPG) has opened up new opportunities and challenges for this sector. This paper examines the role and importance of small scale industries in India, problems they encounter and the performance in terms of their contribution to the overall growth of the Indian economy [1].

Ess Enn Auto CNC Private Limited is one of the leading small scale units in the field of precision machined components for the past 30 years in Bangalore. It has an annual turnover of over USD $1 million and has strength of over 60 employees. As a proof of the Company's performance, they have received recognition from The State Bank of India (our bankers) for obtaining ISO 9002 under Project Uptech Quality Support Scheme, awarded by TSPT, ISO 9001 (1997) and with a DUNS number 65-030-4210. The Company was started by Mr. H.D. Srihari in 1975 as a supplier to MICO (BOSCH - India). The manufactured parts are being used by Automobile, Aerospace, Power Tools, Hydraulics, Electrical and Electronic industries. More than 70% of the parts produced are exported to OEMs in UK, USA, Canada and other parts of Europe. It is located in the heart of Bangalore city, with two units of 102.2 m² housing more than 50 machines with sufficient space for further expansion [2].

2. PROBLEM STATEMENT

The enthused customers of Ess Enn Auto CNC raised the production demand which could not be fulfilled with existing facility. In order to continue serving increased customer needs, Ess Enn planned to acquire nine additional new machines. The space constraint provided an opportunity to integrate lean techniques into the facility layout to accommodate all the new machines and to optimise the material movement with minimal investment. There was a strong need to change the plant layout by integrating lean techniques.

3. LITERATURE REVIEW

3.1 Importance of Layout in Lean Manufacturing

Lean manufacturing focuses on reducing waste and non-value adding activities, and includes forms of just-in-time (JIT) strategy. The waste can be overproduction, defects, unnecessary inventory, inadequate processing, excessive transportation, waiting and unnecessary motion. Firms measure their degree of commitment to lean production via total quality management (TQM) and JIT programmes. However, the implementation of lean management in a manufacturing system requires overall change in the company culture. Lean manufacturing systems are designed for a smooth demand. Layout and kanban system play an important role in materials flow. The group technology is the key to implement smooth material flow and JIT production [3].

3.2 Group Technology and Cellular Manufacturing System

Group technology (GT) is based on the principle of grouping similar products into families with respect to processing. A manufacturing cell designed for each family of products, consists of few/several dissimilar machines to complete almost all operations required for finishing the products. As the range of products manufactured by each cell is high, the workers should be multi-skilled to operate more than one machine in order to achieve work balance among them workers and machines. The advantages of GT are cost reduction, decreased production flow time, increased utilization, reduced inventory level, better quality control, and fast response to product change. It is found that these advantages contribute to related improvements in innovation rate, production cost, quality assurance, delivery promises, customisation and market image of the organisation. The cellular manufacturing system (CMS) is an important sub category of GT [4]. The cellular layout is designed with a static picture of demand, capacity, and product attributes, all of which will change with time. Thus, the performance of a cellular layout would also be expected to deteriorate over months or years of changes, resulting in layout changes [5]. Wemmerlov and Hyer [6] surveyed a variety of US CM users and found load and labour balancing to be the most frequently mentioned problem related to CM implementation. Several companies have reported reductions in machine utilisation and increased equipment needs as additional disadvantages. Saeed Zolfaghari and Erika Roa [7] proved that Hybrid layouts can address the issues with CMS.

3.3 Hybrid Layouts

Zolfaghari and Roa [7] have presented the basis for development of the hybrid system. Hybrid manufacturing system (HMS) is a combination of the traditional job shop and CMS. The grouping of parts into part families in CMS, leads to minimisation of material handling cost and setup times in the system. First, the production layout of the hybrid model has the ability to be used either as a HMS or as a CMS. Secondly, the layout flexibility of the model allows for a variety of products to be processed. These parts could be a mix of grouped parts and independent (i.e. non-family) parts. Therefore, it allows for more parts to be processed in the same CMS. In other words, the hybrid system possesses the advantages of CMS and job shop.

3.4 Designing Layouts

The layout of the HMS is similar to CMS. The difference between a hybrid system and a CMS is the arrangement of equipments inside the cell. The design of the HMS aims at reducing intra-cell movement and eliminating inter-cell movements, but the reduction of
the former are comparatively low in HMS design [7]. Gervasi and Gavrilova [8] explain about facility layout problem (FLP) method. It helps in minimising total travelling time, total cost, total delays, maximum quality, maximum flexibility, and maximum space utilisation. This FLP method uses the Quadratic Assignment Problem (QAP). It calculates the maximum number of combinations n! for given n departments and n locations. In this method, it is difficult to reach the optimal solution, even with a computer, due to the huge number of trial iterations. For example, if number of facilities are 30, the computer has to perform about 2.65E+32 trials which is very difficult. Dorf and Kusiak [9] explain Computerised Relative Allocation Facilities Technique (CRAFT). CRAFT is most popular heuristics approach. The CRAFT algorithm keeps on moving the cells of same size and located adjacent to each other, to optimise the distance travelled by the products. After simulation, the CRAFT method suggests a layout with least material movement cost. However, there are other parameters missing such as total time in system, waiting time, or utilization. For CRAFT method, the cells should be of same size which is not applicable in all cases / industries.

**Fig. 1 Systematic layout planning**

Computerised relationship layout planning (CORELAP) generates a layout on the basis of total closeness rating for each department. CORELAP processes a number of departments, relationships weights, relationships cut-offs (in case of from-to chart), partial adjacency value, and relationship or from-to chart through a simple spreadsheet with some programming interface. The CORELAP algorithm generates layout, and calculates numerical closeness value and distance between the departments [10]. Automated layout design program (ALDEP) is quite similar to CORELAP except for the fact that it breaks the ties for entering departments randomly and the first department to enter is also chosen randomly. ALDEP processes a number of departments, departmental areas, building length, building width, sweep width, number of layouts, relationships weights, relationships cut-offs (in case of from-to chart), and relationship or from-to chart in a simple spreadsheet with some programming interface. The ALDEP algorithm generates the layouts and adjacency matrix, and calculates numerical closeness value [9].

3.5 Systematic Layout Planning

Chase and Chienf [10] explain systematic layout planning (SLP). In SLP the relationship chart, that is the quantitative matrix containing the level of interaction between pairs of departments, is prepared. Adjacency graph relates the arrangement of the departments to represent the relationship data in a graphical way. When the space requirements for the departments are added to this relationship diagram, then a space relationship diagram is constructed. Finally, any number of other considerations and constraints that are not captured in the relationship data or the space data, can be incorporated in the space relationship diagram to generate a layout alternative. Figure 1 shows step by step approach of SLP method.

After reviewing all techniques for designing layouts, the group technology can be used to group the product and to decide about the equipments in the cells. To accommodate more flexibility in terms of product mix and volume, and to lengthen the life of the layout, 'U' type or 'S' type cells are not formed. For deciding the position and sequence of these functional machines, systematic layout planning (SLP) can be used as it allows user to incorporate many constraints such as ease of supervision, employee and employer psychology, etc [11].

### 4. DATA COLLECTION AND ANALYSIS

Data collection and analysis involve collection and analysis of various required data. Systematic Layout Procedure (SLP) was employed for solving this layout problem. The reason for employing this SLP approach among several other approaches is clearly described in Section 3. The current section explains the first six of the total eleven steps of SLP methodology.

4.1 SLP- Step1: Data Collection

Product volume, variety, processing equipments, routing, processing and set up time, and batch quantity of 85 products were collected. All the information was entered in an excel sheet named ‘Product Details’. The equipment availability data along with quality rate were entered in another excel sheet named ‘Equipment Details’. These two sheets were connected through ‘Visual Basic for Application (VBA)’ back-end program to calculate equipment utilisation, and fraction of equipment usage for particular operation of each product. Ess Enn Auto CNC Limited has two production units separated by 0.8 km from each other. The Unit is for their own building, which has under ground floor, ground floor, first floor, and terrace. The underground, ground floor, and first floor contain production equipments and the second floor terrace has dining shed for Ess Enn employees. Unit 2 is a rented building, which has ground floor and a small first floor. Unit 2 ground floor contains production equipments and the small first floor is used as storage. The exact dimensions of the building, equipments, equipment auxiliaries (control panel, transformer, rack, trolley, etc), and utilities were measured to create current layout in AutoCAD software by using variety of colours to differentiate the objects.
4.2 SLP- Step2: Material Flow Analysis

In material flow analysis, the flow intensity between equipments is analysed. The base data for these analyses are ‘Product Details’ excel sheet. An excel sheet named ‘From-To Frequency’ exhibits the flow intensity between equipments. This flow intensity clearly shows the number of times the products flow between equipments. The important inputs to prepare flow intensity chart are monthly volume, transport quantity, and product routing. Based on the product processing sequence, the products are categorised. Products having similar processing sequence are put in one family and the number of transportations are added together. ‘Sequence’ excel sheet contains sequence number, number of material movement, number of products and names of products that belong to that family, and operations of that family. With the product family data, operation sequence, and exact dimensioned AutoCAD drawings, the aggregate distance travelled by each product family is calculated. This distance data is depicted in a pareto chart to find those vital few which cause the major distance travelled.

4.3 SLP- Step3: Activity Relationship Analysis

In activity relationship analysis, A, E, I, O, U, indicate the closeness relationship between two activities denoting: absolutely essential, essential, important, ordinary closeness, and unimportant. This analysis is basically a qualitative analysis. The data is collected from shop floor engineers who are quite familiar with the process and equipments. In the current layout problem, this activity relationship analysis is not essential. But, when applying SLP methodology in process based industries, it is very important to characterise the relationship between departments or equipments. In activity relationship chart, the equipments are listed in horizontal and vertical direction. The qualitative relationship between each machine is evaluated and represented with letters A, E, I, O, and U. Letter ‘A’ is highly important, and ‘U’ is least important. This activity relationship chart will be one of the inputs to space relationship diagram.

4.4 SLP- Step4: Relationship Diagram

Relationship diagram is a quantitative analysis that reveals the potential good relative position decision. It provides equipment relative positioning by considering product flow frequency, and this diagram is main input to space relationship diagram. It furnishes quick overview of entire products in a company. Figure 2 shows the relationship diagram. The frequency between equipment is calculated from step 2 - material flow analysis.

4.5 SLP- Step5/6 - Space Requirement and Availability Analysis

This step involves capturing the available floor space and the space required for individual equipment along with its auxiliaries such as control panel, electrical transformer, rack, trolley, operator, etc. The space required for its maintenance and chip removal also measured. The space utilisation is measured in terms of equipment area per unit of floor space. This approach leads to exact measurement of space utilisation. If space utilisation is measured in terms of number of equipments per floor, by installing many small machines in a floor would show improvement, which would lead to wrong decision.
used for aisle, inventory, and utilities. The remaining 26% of area was not being used due to improper layout configuration. Based on the detailed analysis, action plans were developed. The space for aisle were reduced and used for equipments by marking proper aisle and installing equipments in both sides of the aisles. The unused space was used for equipments by placing them in proper orientation.

5. PROBLEM SOLVING

This section involves deriving a solution from the analysis carried out in the previous one. The remaining steps from seven to eleven of SLP are performed in this section.

5.1 SLP- Step7: Space Relationship Diagram

Space requirement diagram is initial concept level layout, which has exact dimensions of the floor, and the equipments. The relationship diagram and space data were used to create the space relationship diagram. The space required for all same type of equipments is made into a single block and depicted in this diagram. The aim of this diagram is to find the possible conceptual location and number of equipments in a floor. Equipments with high flow intensity are located close to each other and space constraint is also considered. Figure 4 is the space relationship diagram of Unit 1 first floor.

5.2 SLP- Step8/9/10 - Practical Limitations/Constraints/Alternate Layouts

The practical limitations and constraints were gathered from shop floor employees and office employees. The alternate layouts were generated on iteration basis, referring these practical limitations and constraints. The problems from previous iteration were eliminated in the next iteration. The alternate layout generation process involved eight to seventeen iterations for each layout. Here, only four major iterations are presented.

![Fig. 4 Space relationship diagram of Unit 1 first floor](image)

**Layout generation: Iteration 1** - The space relationship diagram was used to create the initial layouts. Once the initial layouts were created, these were cross checked with the practical limitations, constraints, and expected results. Three major issues were identified with iteration 1 layouts. One of the major problems was Unit 2. It didn’t have proper control over the processes and equipments. A brainstorming session was conducted to find out solution for this issue. In the brainstorming session, many innovative ideas were suggested by all participants. According to this, the second floor in Unit 1 will be built and planned equipments in Unit 2 will be shifted. One more issue with iteration 1 layout was that the Unit 1 first floor space was under-utilised. This problem was addressed with relocation of equipments and installing few more equipments. The last issue with iteration 1 layout was that the Unit 1 ground floor housed several equipments, which led to troublesome material and operator movement. This problem was addressed by relocating the equipments in different positions and orientations.

![Fig. 5 Iteration 4 layout - Unit 1 second floor](image)
respectively. These layouts are iteration 4 layouts, which are final layouts that satisfied all the practical limitations and constraints. These were evaluated to find different layout deliverables.

Fig. 5 Iteration 4 layout – Unit 1 first floor

5.3 SLP-Step1: Evaluation

Layout evaluation involves estimating the layout deliverables such as space utilisation, material movement distance, material handling cost, and space saved. Evaluation is performed to validate the actual results against the intended ones. This step is essential to confirm that the selected layout is an optimised layout.

Fig. 7 Iteration 4 layout – Unit 1 ground floor

Space utilisation calculation- The space utilisation was calculated for new layout and compared. The space utilisation of new layout is 0.2825 m²/m² and current layout is 0.2025 m²/m². So the percentage of improvement achieved is 39.51%.

Material movement distance calculation- Spaghetti diagram was used to measure the material movement distance. Spaghetti diagram is a flow charting method that uses a continuous line to trace the path of a part through all phases of manufacturing. It is a way to view the material flow in a process and illustrate the wastes of transportation and motion that should be eliminated in producing a more lean operation. The distance travelled for every product family was measured from spaghetti diagram (refer Fig. 9) and total material movement distance was calculated for new and current layout.

Fig. 9 Spaghetti diagram

The material travel distance for current layout is 113 km/month whereas 14 km/month for new layout. There is a drastic improvement due to optimisation of the floor to floor material movement. The total material travel distance saved is 99 km/month. This saving results in shortening the lead time, reducing WIP, and creating a healthy environment for enabling FIFO, Kanban, and small lot production.

Material movement cost calculation- The material travel distance is used as the main input for calculating the cost involved in material handling. Operators are employed for moving the material from machine to machine, and floor to floor. Small truck is used for transporting material from one unit to another. The cost incurred in floor to floor and machine to machine material handling of new layout is INR 394 /month. The cost incurred in unit to unit material handling is INR 5288/month due to material truck and driver. The intra unit (floor to floor and machine to machine) material handling for the current layout is INR 3175 /month, and for the new layout is INR 394/month. Inter unit (unit to unit) material handling is completely eliminated. So, INR 5288/month is saved. Therefore, the total saving in material handling cost is INR 8069/month.

Dedicated space for future expansion calculation- Dedicated space for future expansion is also one of the essential deliverables of this project. This is 14 m² in current layout and 33 m² in new layout. The improvement achieved is 135.7%.

Fig. 8 Iteration 4 layout - Unit 1 underground

Fig. 6 Iteration 4 layout – Unit 1 underground
5.4 Financial Analysis

Financial analysis is an important part of project evaluation. It is done to calculate the return on investment. Savings achieved, investments on the project, and depreciation factor are the inputs for performing financial analysis. Quotation for building the second floor and equipment relocation were obtained from many contractors. One quotation was selected based on reliability, quality, timeliness, and cost. With the given input, the ROI is calculated as 1.83 years.

6. RESULTS AND DISCUSSIONS

The results achieved are shown in a radar chart (Fig. 10). In the radar chart, larger area shows current layout deliverables and smaller area shows new layout deliverable. Due to the implementation of new layout, the space utilisation will be improved from 0.21 m²/m² to 0.28 m²/m², material handling distance will be reduced from 113 km/month to 14 km/month, material handling cost will be reduced from INR 8463/month to INR 394/month, Unit 2 rent INR 48000/month will be completely eliminated, and the space for future expansion will be increased from 14 m² to 33 m².

Since the new layout is capable of achieving intended aim, the implementation work of new layout has started. The company has planned the implementation task in detail. Enough care is being taken not to disturb the regular production activities during this implementation phase. It is expected to complete the implementation entirely by the end of May 2010.

7. CONCLUSIONS

The lean management system promotes lean production by providing a framework for integrating (1) a carefully designed and maintained web of cooperative human relations, (2) a system for continuously upgrading the technical and problem solving skills of employees and, (3) relentless systematic study and application throughout the organisation to improve quality, speed, cost and flexibility. These three factors strengthen the organisation in the appropriate direction that leads to long term survival and growth. The essence of lean management system is an expanded flow of information within the company and a continuously enhanced ability to learn from that information which leads to improve the process.

Lean techniques are basically scientific approaches that continuously improve quality, speed, cost and flexibility by eliminating waste or non-value added activities. The work presented here was carried out by adapting group technology, cellular manufacturing system, and systematic layout planning, which are basically scientific approaches and part of lean techniques that led to improve the quality, speed, cost and flexibility. This work has added value to Ess Enn Auto CNC through the successful execution of the project. Ess Enn Auto CNC had enough knowledge about lean philosophy and was practicing lean techniques. The company is proudly exhibiting its capability as lean organisation to its customers by executing the recommendations from the project work.

The success of an organisation is decided based on its ability to exceed customer requirements consistently. Lean philosophy continuously encourages people to implement ideas to achieve that. Ess Enn Auto CNC is one such company delivering products that enthuses its customers consistently. According to lean philosophy, the employees are more important resources than machines. The new shop floor layout offers a safe environment to the employees. The research effort has given direct results such as cost saving, lead time improvement, and delivery time improvement along with indirect results such as improvements in employee morale, and working environment.

8. REFERENCES


