

Facility and Process Layout Analysis of an SME using Simulation: A Case Study of a Manufacturing Company

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Abstract: This case study has been carried out on facility and process layout analysis in a manufacturing company (a small and medium enterprise). This XYZ company is a supplier and manufacturer of textile machines, parts & spares, conveyors, air handling machines, double bed fusing machines, electric and gas heaters etc. The company primarily deals with automobile parts & components, working as tier one supplier for two companies say company A & company B and tier two supplier for a company C. It is primarily a job shop company which caters to many different products with variability in demand. This paper demonstrates the effects of modifications in facility and process layout, on the productivity and cycle time using simulation. This study shows that there is a significant reduction of cycle time by better material handling leading to better productivity. The current and proposed process solutions were modelled, simulated and analyzed using ARENA simulation software.

Keywords: facility layout, process layout, SME (small and medium enterprise), cycle time, ARENA simulation, productivity improvement

I. INTRODUCTION AND LITERATURE SURVEY

The industrial world is becoming competitive and creating competition in multiple items [1] in SMEs context which is differentiated from large scale industries. Therefore, SMEs always try to focus on excellence in their manufacturing products and services. In the context of Indian economic growth, the importance of SMEs in the manufacturing sector is burgeoning which is testified by their contribution [3, 5]. These SMEs also confront with increased competition from cheaper manufactured products from such countries as China and India and they are consequently struggling to develop appropriate strategies for competing with them [3].

This paper describes the facility and process layout is done using Arena simulation system. Now a days, Arena simulation is very prominent modeling software which is more aware of the potential benefits of simulation. The power of Arena is in providing the user with the capability to model quickly and easily with a tool that is customized to application [12]. It is an easy-to-use, powerful modeling and simulation software tool that allows the user to construct a simulation model and run experiments on the model [15]. It is a one-step, graphical modeling and animation system that is based on concepts from object-oriented programming and hierarchical modeling [13] in which we can design the model, get output and it gives the simulation analyst a decision support tool that combines the capabilities and power of a simulation language with an easy user interface for model building [12]. Arena simulation software also provides model in the business to improve decision making [14]. These are the following steps to follow to solve the problem. 1. Identify the problem. 2. Built the Arena simulation model of the process. 3. Transform the business to implement the right ones for the business and 4. Repeat the continuous process that successful organizations undertake to ensure that they are staying ahead of the competition.

Arena simulation software provides the capability to capitalize on business performance [14]. These are follows: 1. Evaluate potential alternatives to determine the best approach to optimizing performance. 2. Understand system performance based on key metrics such as costs, throughput, cycle times, equipment utilization and resource availability and 3. Reduce risk through rigorous simulation and testing of process changes before committing significant capital or resource expenditures.

A facility is an entity that facilitates the performance of any job. It may be a machine tool, a work center, a manufacturing cell, a machine shop, a department, a warehouse, etc. [11]. The facility layout problem is concerned with finding the most efficient arrangement of m individual departments with unequal area requirements within a facility [7]. In other words, it is an arrangement of everything needed for production of goods or delivery of services [11] and the placement of the facilities in the plant area often referred to as “facility layout problem”. It is known to have a significant impact upon manufacturing costs, work in process, lead times and productivity [9]. A good placement of facilities contributes to the overall efficiency of operations and can reduce up to 50% of the total operating expenses [10]. Process layout groups facilities with similar functions together (resources of the same type). Organizations with wide variety of product often prefer process layouts [9]. As stated above, the objective of the facility layout problem is to minimize the material handling costs inside a facility subject to two set of constraints: (1) department and floor area requirements and (2) department locational restrictions (departments cannot overlap, must be placed within the facility, and some must be fixed to a location or cannot be placed in specific regions) [7]. Moreover, Ashish et al. [8] considered block layout problem (BLP) in their study to solve the optimization problem which deals with finding the best arrangement of departments in a functional or a job shop facility. The departments may have equal or unequal areas and can have interactions between them. The objectives of the BLP include: flow-distance, material handling devices cost, average work-in-process (WIP), flexibility, area costs, number of machines per department, and so on [8].

In spite of the vital role of SMEs in Indian economic growth, they face a lot of problems due to their unorganized approach of the manufacturing and production systems; lack of robustness and flexibility to deal with the demand fluctuations [4]. The facility layout problem (FLP) is a well-studied combinatorial optimization problem which arises in a variety of problems such as printed circuit board design; layout design of hospitals, schools, and airports; backboard wiring problems; typewriters; warehouses; hydraulic turbine design; etc. [2]. Onkar et al. [4] described that most of the manufacturing SMEs in India have improper facility and process layout which are adversely impacting the: (1) Flow of material and inventory from one workstation to another, (2) Machine utilization, (3) Waiting time, (4) Productivity. Some others parameters which affects productivity are (5) Manual material handling, (6) Unskilled and untrained labour, (7) Substandard Equipment, (8) Inefficient Plant layout, (9) Low degree of automation, (10) Inefficient data management, and (11) Limited space for plant expansion etc.

The cumulative effect of inefficiencies in the above parameters are detrimental to the growth of SMEs which ultimately makes them sick. So, it is quite evident that dealing with these problems needs a holistic approach of problem solving at strategic, operational, and tactical levels but Gunasekaran et al. [6] noted that the problems observed are not only strategic, but also operational. So, here we have developed an operational strategy to optimize system utilization while controlling the bottleneck by selecting the necessary modification that improves the productivity. In recent years, many shop-floor improvements have been achieved through process redesign, including changes in layout, employee responsibilities, and work methods [6]. Integrating various functional groups within a manufacturing organization can also improve both productivity and quality [6]. The immediate gain will be reduction in the work-in-process inventory as well as a reduction in scrap, since any defect is identified immediately [6]. In the plant layout design, facility and process layout are applied to improve the layout and productivity of the plant where this method is complicated. We compare present and proposed plant layout of the XYZ company and analyze whether the proposed model is simplified and more effective than the existing system

In this paper, we have described introduction and literature survey in section 1. Section 2 gives a brief overview about the company relevant to this research and section 3 relates the operational department and functions of XYZ Company. Section 4 outlines the problem description, followed by simulation results and analysis in section 5. Section 6 briefly outlines the conclusions and limitations.

II. BACKGROUND OF THE COMPANY

XYZ manufacturing company is having more than 50 employees altogether. It is one SMEs of the manufacturing company and it is located in Kanpur, Uttar Pradesh, India. We are considering only facility and process layout which consists of many departments of the company. In these departments, there are different operations which involve 11 process steps from milling operations to final positions headed by around 15 individual operators. The operators do these operations on the different machines like milling, drilling, tapping, and grinding etc. There is no extra person

assigned to carry one semi-finished or finished products from one machine to other machine. These are done by the individual operators who operates the particular machine. This is one of the reason for delaying. The employees of this company allowed to work in two shifts (day and night).

This XYZ company is the supplier and manufacturer of textile machines, parts & spares, conveyor, air handling machine, double bed fusing machines, electric and gas heater etc. so, this company basically deals in automobile parts and components. It is a job shop company which caters to many different products with variability in demand. The company strives to achieve continuous improvement in its processes and uses some of the latest CNC machines in addition to the manually controlled machines. The products vary from highly critical low tolerance billet aluminum parts for one big company named A to cast iron parts for other one named B. Similarly the machines for these different jobs vary in terms of quality and tolerances. The part (ring stand) for the textile machines in company B is cast iron. This particular part has been constantly ordered by company B for the past 18 years and has been the bread and butter for the company. There is a slight variability in the orders per month but the company on an average makes about 1200 parts per month. The raw material which is a raw casted part is supplied by company B and it is worked upon by XYZ Company. There is a section completely dedicated for this particular part and the section has a job shop layout.

III. THE OPERATIONAL DEPARTMENTS (MACHINE SHOPS) AND THEIR FUNCTIONS OF XYZ COMPANY

The XYZ manufacturing company has four machine shops in the manufacturing plant and their functions are done in eleven processes which are carried out in these machine shops. Here are descriptions of these machine shop processes and their functions are listed in the Table I.

TABLE I
VARIOUS MACHINE SHOPS AND THEIR FUNCTIONS

SN	Machine shop	Functions
1	Milling shop	Milling of solid materials may involve a horizontal or a vertical milling machine, depending on the position of the cutting tool. In this machine, the work piece moves against a rotating slicer.
2	Drilling shop	It usually involves moving the drill to the surface that needs a hole, in a machine shop usually use a drill press, where the material to be drilled is placed in a tool (chuck) and secured underneath a drill head that moves up and down and uses different bits.
3	Tapping shop	Tapping is the process for producing internal threads using a tool (tap) that has teeth on its periphery to cut threads in a predrilled hole. A combined rotary and axial relative motion between tap and workpiece forms threads.
4	Grinding shop	Grind is one of the final processes in machining of materials. Grinding improves the surface of the material being machined, smoothing the rough edges, and ensuring uniformity of surface.

IV. PROBLEM DESCRIPTION AND ANALYSIS

The cast part which the company supplies to company B is the single constant part in the whole portfolio of products which the company makes. The problem here is that the machine costs are increasing due to increasing labor costs, while the price company B pays for this particular part has remained constant in all of these 18 years. Another problem which XYZ is facing with this part is that the total output per month has been limited to more or less 1200 units owing to a slow cycle time. XYZ wants to increase to about 1600 to 1700 units per month to be able to cater to the variability in demand for this product and also wants to reduce the total amount of time utilized in the manufacturing of this product each month so that it may utilize any time saved in manufacturing some other product by taking orders for new parts or more parts from other companies.

The cast iron part which we are studying is delivered to the plant as a raw casted item by company B. This part is stored in the raw material inventory store in abundance.

Please refer to figure 1 for a detailed view of the present layout of the plant. Here we see the placement of the various machines like the milling, drilling and tapping machines. The raw material first arrives at the Horizontal Milling machines marked by '1' in the figure. After the first milling operation, it moves to the 9mm drilling machines marked by '9' in the figure. There on the part is moved to the different drilling operations marked '4', '5' and '6' in the figure. After these drilling operations the part is moved to the tapping machine marked '10' in the figure. The final operation of vertical milling is done on the vertical milling machine market '2'.

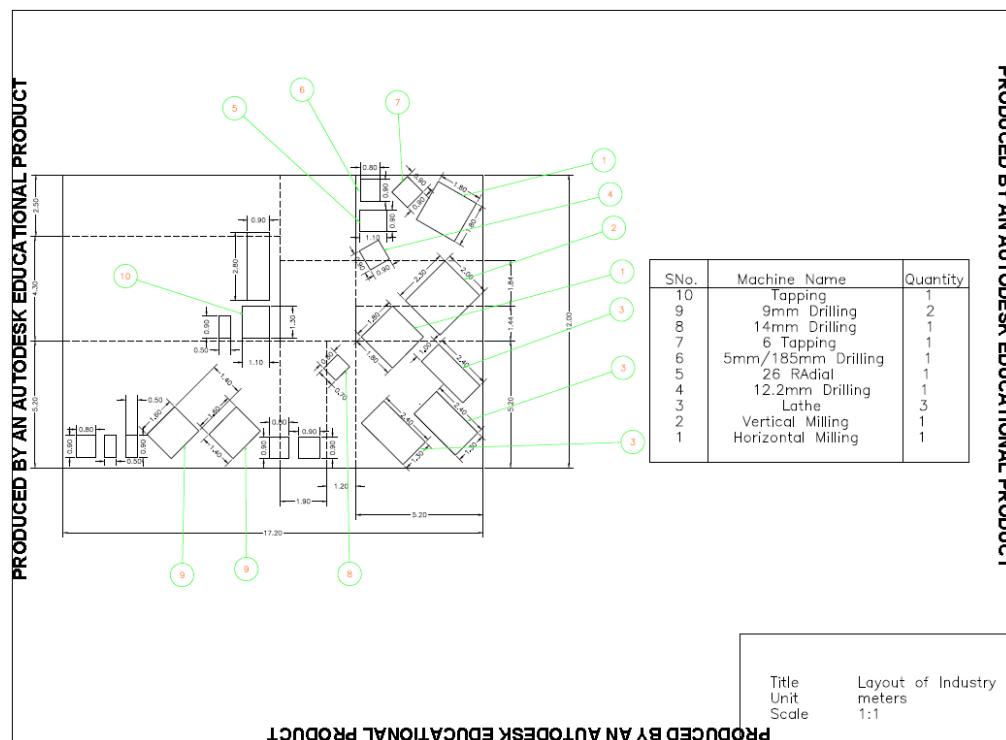


Fig. 1: Present Layout of the XYZ Plant layout

The raw material is carried by hand to the first machine. There is one labor which is utilized for this who carries 2 pieces at a time. This same labor is used for transporting the work in progress pieces from one machine station to another. The major issue comes at the 9mm drilling machines. At these machines the part is fixed onto a complicated and heavy Jig. The whole unit is setup vertically for drilling and it has to be rotated 3 times manually for the operation to be complete. This rotation has to be done with the help of a helper. Here the helper is the same labor which is used for the inventory handling. Hence the operator of the 9mm drilling machine has to wait for some time before the helper arrives and helps in rotating and fixing the jig. This is one of the major problems in the layout. As can be seen from figure 1, the 9mm drilling machines are placed away from the area where the milling machines are placed. Hence while the material handling labor is working near the milling machines, he may be required at the 9mm drilling station, thereby delaying the operation by quite some time.

Another issue is the back and forth movement of the work-in-progress job in the area, from the milling machine area to the 9mm drilling machines and then back to the other drilling operations and then again to the tapping machines. This back and forth movement in a haphazard way costs the process a lot of time.

The raw material inventory storage is quite far from the machining area. And bringing the raw material from the storage to the milling center takes quite some time.

Another issue is the inadequacy of tools. There are tools which are required for tightening the job on the machine. Operators from different machines take the tools from each other but do not bother to return them. The operator then sits idle till the tool is returned to him.

Problems

- Back and forth movement of the material
- Dependency on a single labor for material handling and helping the operators
- Distance from the raw material storage area
- Idle operator due to non-availability of tools

Causes

- Inefficient Layout
- Labor inadequacy
- Lack of in-plant transportation system
- Inadequacy of tools

V. SIMULATION RESULTS AND ANALYSIS

A. SOLUTION FOR THE PRESENT LAYOUT

The layout of this company has come up with the addition of machines over time and they have been placed as and where the location was available. We now have redesigned the layout for higher efficiency and quicker transportation of the work in progress jobs from one station to another. As seen from fig. 2, the machines would now be placed closer to each other.

There would be various benefits of this layout. Firstly, the transportation between the machines would reduce drastically and secondly, the helper which is required for various job fixings, would be available near the 9mm drill machines and the operator would not have to wait for the helper to arrive. This layout change itself aids an increase in the output of 7.7% as has been detailed in fig. 3a, 3b, and 3c.

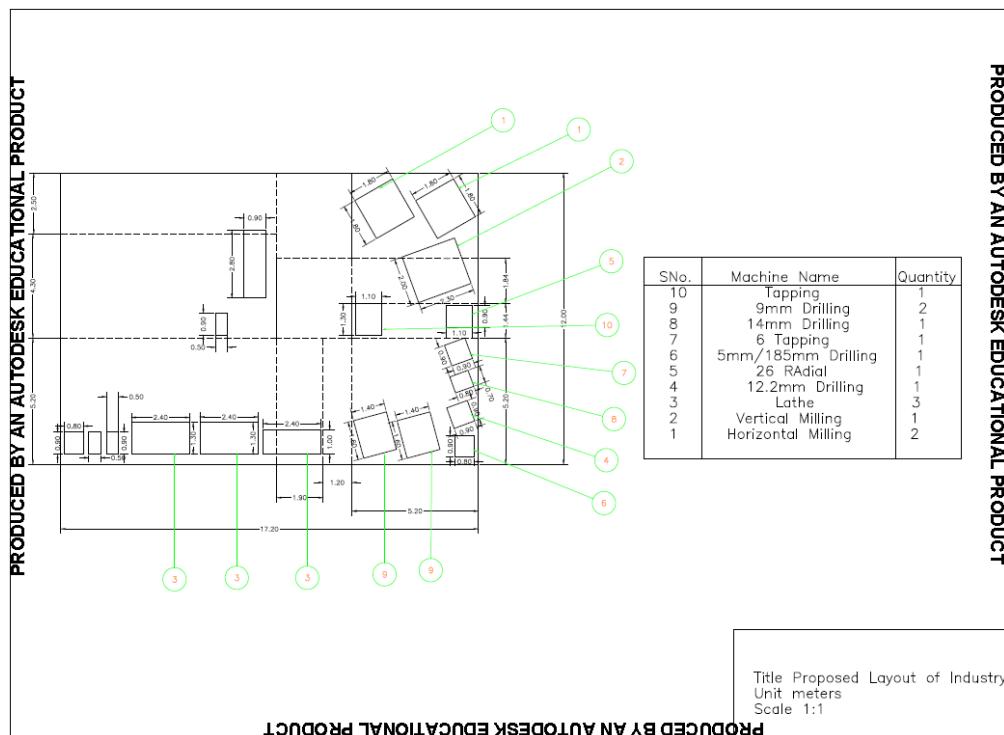


Fig. 2: Proposed Layout of the XYZ Plant layout

TABLE II
PROCESS DISTRIBUTIONS AND PARAMETERS (CURRENT MODEL)

Operation	Distribution	Parameters(in minutes)	Std Deviation
Horizontal milling	Uniform	26-31	
Vertical milling	Normal	mean 6.6	0.4
12.2 mm drilling	Uniform	10-12	
26mm radial	Normal	Mean 5.7	0.5
5 mm/185 mm drilling	Uniform	12-14	
6 mm tapping	Normal	Mean 2	0.4
14 mm Drilling	Normal	Mean 6.2	0.4
9mm drilling	Uniform	27-35	
5 mm tapping	Uniform	13-17	
Delay 1	Uniform	1-1.5	
Delay 2	Uniform	1-1.5	
Delay 3	Uniform	1-2	
Grinding	Uniform	1---2.2	

Suggested Solutions:

- Change in Layout.
- Concrete flooring of the area from the inventory shed to the machine area.
- Use of small trolleys for the transportation of the work pieces.
- Dedicated toolboxes for every machine.
- Addition of extra machines to achieve higher production rates.

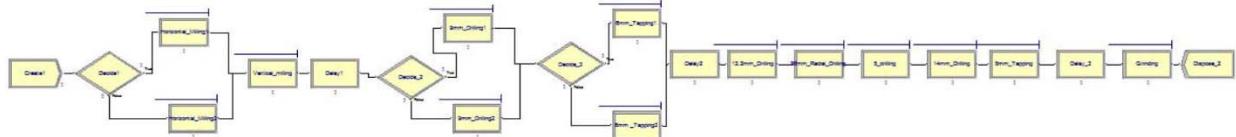
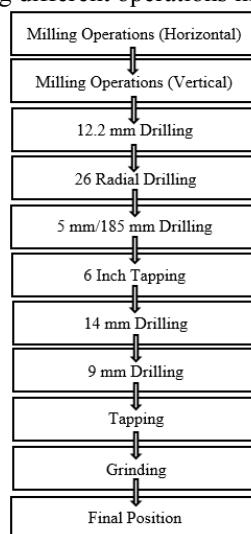


Figure 3a: Arena Process Flow Model for present layout

Operations Involved: There are the following different operations involved:



As seen in the figure 3a, we have developed a process flow model for the present layout of the plant. We had taken sample timings and used them to fit the distributions in this system. We ran this system, for a sample shift of 20 hours per day, and 30 replicated runs. We found that this plant is able to produce 65 units per 20 working hours given the present layout. The details of the results of this model can be viewed in table II and appendix.

We then redesigned the facility to create a new layout as seen in Figure 2 to remove the excess movement times between the different machines.

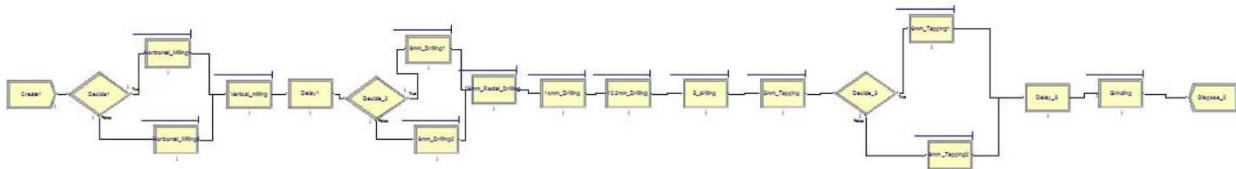


Figure 3b: Arena Process Flow Model for redesigned layout

In figure 3b, we see a new flow chart based on the relocation of the machines and a change in the sequencing of the drilling operations following shortest processing time dispatch rule. It was run for the same duration of 20 hours and 30 replications. After these runs we found that there was an improvement in the number of units produced. The observations were as follows:

- Now the total number of units produced was 70 for these 20 working hours.

- This is an improvement of 7.7% by just changing the location and sequence of order of the drilling machines.
- We observed that the milling machine was bottleneck of this process flow.
- On referring to table III, which has the details of the model, we see that the milling machines have the highest utilization of average 98%.

The detailed results of this model can be seen in table III and appendix.

Hence we added one more milling resource and another 9mm drilling machine and ran the model. The results showed an increase in the number of products produced by just 2. Hence we subsequently added more machines. The bottleneck kept shifting to different machines. Finally we added 2 milling machines, one 9mm drilling machine, one 5mm tapping machine, one 12.2mm drilling and one 5mm drilling machine. We can see the resultant process flow model in figure 3c.

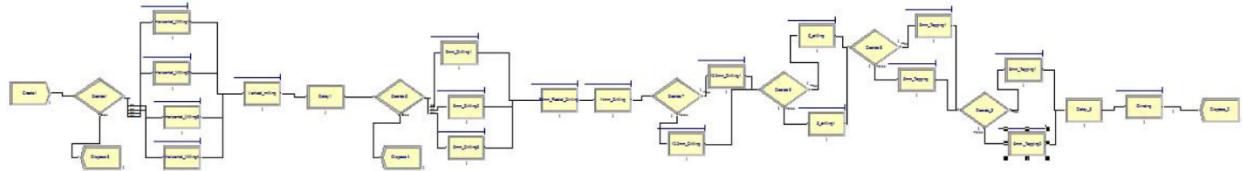


Figure 3c: Arena Process Flow Model for final layout

The observations were as follows:

- The number of products produced went from 72 to 99 in the 20 working hours.
- This is a 37.5% improvement over the last layout.

What we saw here was a special case of sequencing where the bottleneck keeps shifting to different machine and there is no change in the output of the plant and finally there is a sudden jump in the output which we see here as from 72 to 99 products. The detailed results of this model can be seen in table III and appendix.

The unique contribution of this paper is that output of the problem that it provides a methodology to computationally solve the model using ARENA software. It is existing methodologies in the literature that address aspects of the facilities design problem and output gets benefit by changing the layout, additional machines, and waiting time.

TABLE III
PROCESS DISTRIBUTIONS AND PARAMETERS (AFTER DELAY REDUCTION)

Operation	Distribution	Parameters(in minutes)	Std Deviation
Horizontal milling	Uniform	26-31	
Vertical milling	Normal	mean 6.6	0.4
12.2 mm drilling	Uniform	10-12	
26mm radial	Normal	Mean 5.7	0.5
5 mm/185 mm drilling	Uniform	12-14	
6 mm tapping	Normal	Mean 2	0.4
14 mm Drilling	Normal	Mean 6.2	0.4
9mm drilling	Uniform	23-28	
	Uniform	23-28	
5 mm tapping	Uniform	0-0.5	
Delay 1	Uniform	0-0.5	
Delay 2	Uniform	0-1	
Delay 3	Uniform	1-2	

VI. CONCLUSIONS AND DISCUSSIONS

In this paper, we have presented a case of simulation based analysis of facility and process layout of a XYZ Company. We have proposed two models with different approaches both leading to improved productivity. After performing discrete event simulation and analysis of the proposed model through Arena Simulation Software, we observed that there is significant increase in the productivity with modifications in current layout as well as the addition of few resources (machines). The value of improvement in productivity in comparison to the cost that incurs for new machine addition is debatable. The investments are quite high with respect to the profit from the improved productivity. The aim of the company is to increase the output from current 1200 units per month to a maximum of 1700 units per month and finally get 37.5% improvement over the last layout with minimum waiting

time. The corresponding profit gained would be limited. Hence, we propose to go for the implementation of the solution which does not require addition of new machines. The analysis of this study proves that if we increase the number of machines and change the job order and machine setup, then definitely increase the efficiency. In practical scenario, it is observed that this company gets competitive advantage through results and analysis. In addition, the results impose that there is less material handling, work-in-progress inventory, waiting time and cycle time to improve the productivity.

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BIOGRAPHY

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APPENDIX

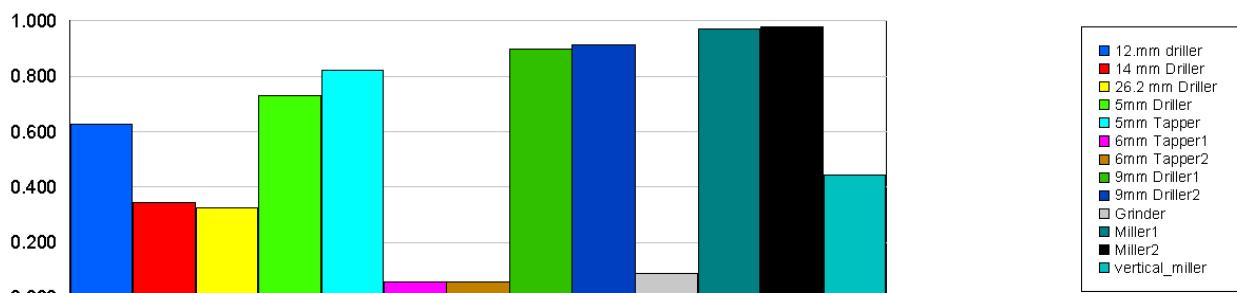


Fig. 4a: Utilization factors of various operations before process flow change with able to produce 65 units per 20 hours and 30 replication

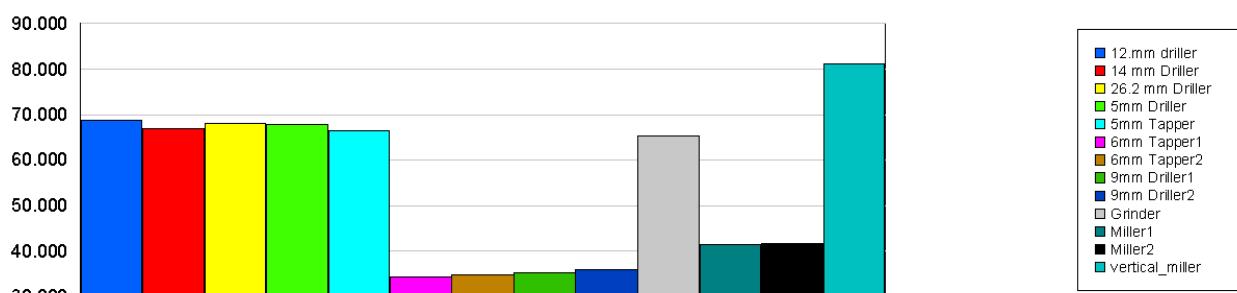


Fig. 4b: Utilization factors of various operations after process flow change with able to produce 65 units per 20 hours and 30 replication

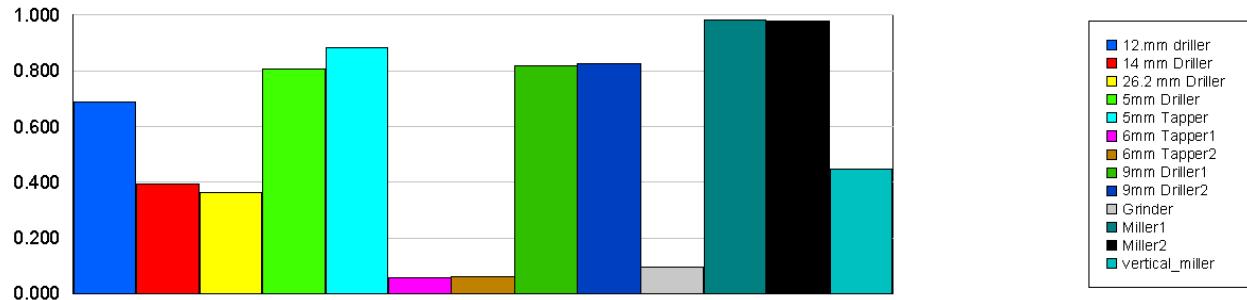


Fig. 5a: Utilization factors of various operations before process flow change with able to produce 70 units per 20 hours and 27 replication

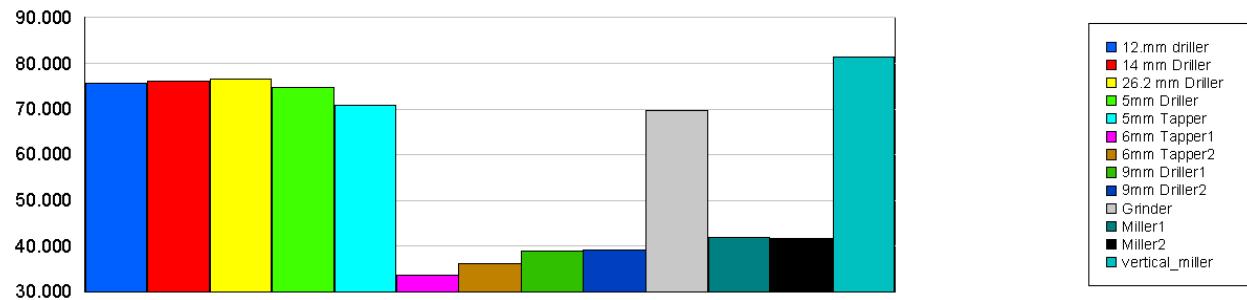


Fig. 5b: Utilization factors of various operations after process flow change with able to produce 70 units per 20 hours and 27 replication

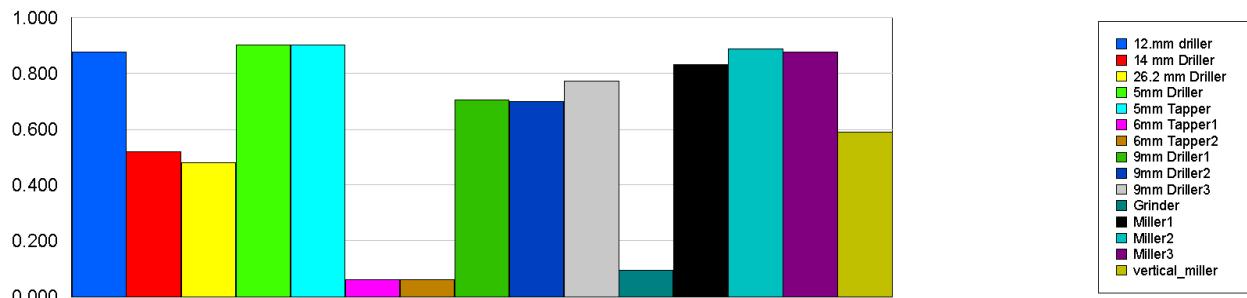


Fig. 6a: Utilization factors of various operations before process flow change able to produce 72 units per 20 hours and 27 replication

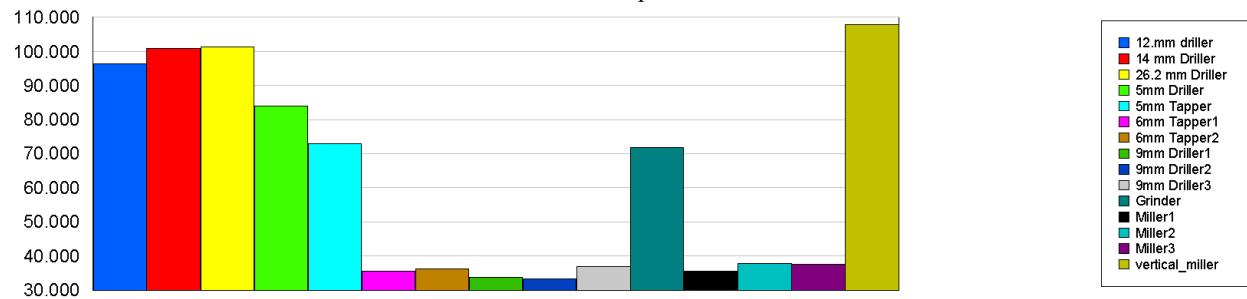


Fig. 6b: Utilization factors of various operations after process flow change able to produce 72 units per 20 hours and 27 replication

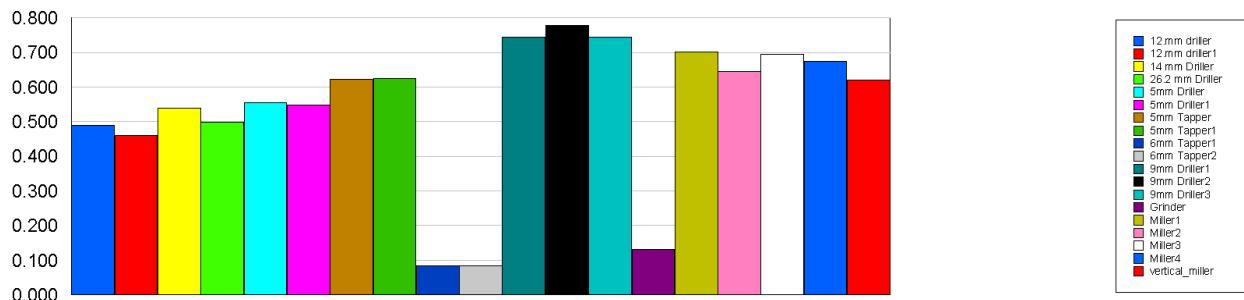


Fig. 7a: Utilization factors of various operations before process flow change able to produce 99 units per 20 hours and 30 replication

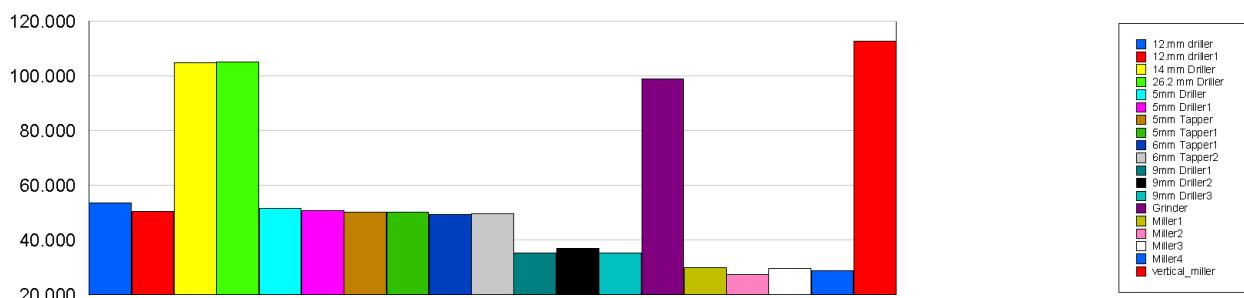


Fig. 7b: Utilization factors of various operations after process flow change able to produce 99 units per 20 hours and 30 replication