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Analysis of Production Line's in an Manufacturing Unit with an Intention to Obtain Line Balancing through Reduction of Cycle Time and Lead Time

*P.VIDYUT CHANDRA, **MEDISETTY SAI CHARAN, **NADIR SUMIRAN, **RAHUL JACOBI, **SIDDHANT UMESH SAWANT
*Assistant Professor, Dept of ME, Sreenidhi Inst. of Science & Technology, Hyderabad, Andhra Pradesh, India
**UG Students, Dept.of ME, Sreenidhi Inst. of Science & Technology, Hyderabad, Andhra Pradesh, India

***Abstract—* Line balancing and sequencing are most useful technique for conducting optimization study on shop floor production layout. In today's technological production environment all organizations are striving to implement lean manufacturing system on the shop floor to achieve productivity enhancement to global benchmarks. Any trail and error approach during line balancing may provide initial results but any further scope for improvement in future is not possible. So our main aim of study is to understand operations performed with respect to time taken in their assigned station in order to reduce the overall transportation time by either combining different operations or any removing machining errors to reduce cycle time as well as manpower involved. This also provided an opportunity on shop floor for better space utilization with better organized look.**

Index Terms: **Line balancing, lead time, cycle time, plant layout and space utilization.**

I. INTRODUCTION

Line balancing and sequencing is one of the core area for optimization study in operations management. The main aim of this analysis is to improve layout in a manufacturing unit with clear focus on improving productivity. Assembly line is a layout sequence of workstations connected together by an automated material handling system. It is used to assemble components into a final product. We made an effort to study the entire layout design of production line right from raw materials stage until finished product output and redesigned layout after thorough analysis of data in line with line balancing techniques. Line balancing depends on many factors. Such as Variance of time among product versions

- Cycle time
- No of stations
- Traffic problems
- Station space
- Transportation networks
- Communication among the groups
- Task complexity
- Reliability

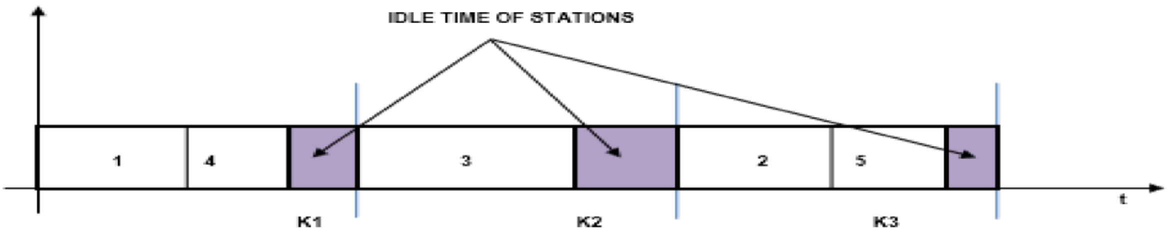

Fig. 1. *Assembly Line Balancing Problem*

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We observed that line balancing functionalities is not typically a concern in the production environment, but has a lot of impact on the total business performance.

II: CITATIONS AND UNDERSTANDING OF TERMS AND DEFINATION

A. Definition

Cycle time equates to speed, and faster is better. However, for the remainder of this thesis, a distinction will be drawn between “cycle time” and “lead time.” In his 1921 Treatise on manufacturing, Henry Ford wrote, The time element in manufacturing stretches from the moment the raw material is separated from the earth to the moment when the finished product is delivered to the ultimate customer.

B. Lead Time and Cycle Time

Lead time is defined as the time from when the customer fixes an order until the customer receives the product. In the scheduling area, lead time measures the offset from when the order is dropped into the system until the goods are delivered. Typically, lead times are written into the internal customer-supplier contracts within manufacturing unit.

- Lead times are a function of the following:
- Manufacturing speed
- Service level
- Amount of inventory on hand

For example, if manufacturing cannot respond quickly and if a high service level is desired, then the organization must either keep high inventory or lengthen the promised lead time. Figure 1.2 shows how the definition of cycle time includes the lead time and time spent in inventory.

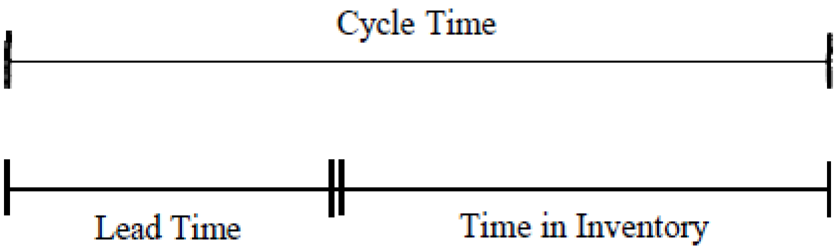

Fig. 2 –Cycle time, lead time and time in inventory

C. Cycle Time

It is inversely related to throughput, decrease cycle time leads to increased throughput, show in the following equation (Mejabi, 2003):

$$\textbf{Cycle Time ,c} = \frac{\text{Total Operating Time}}{\text{Quantity of Production Produced}}$$

$$= \frac{1}{\text{Throughput}}$$

$$\textbf{Production Rate, p} = \frac{1}{\text{Cycle Time, c}}$$

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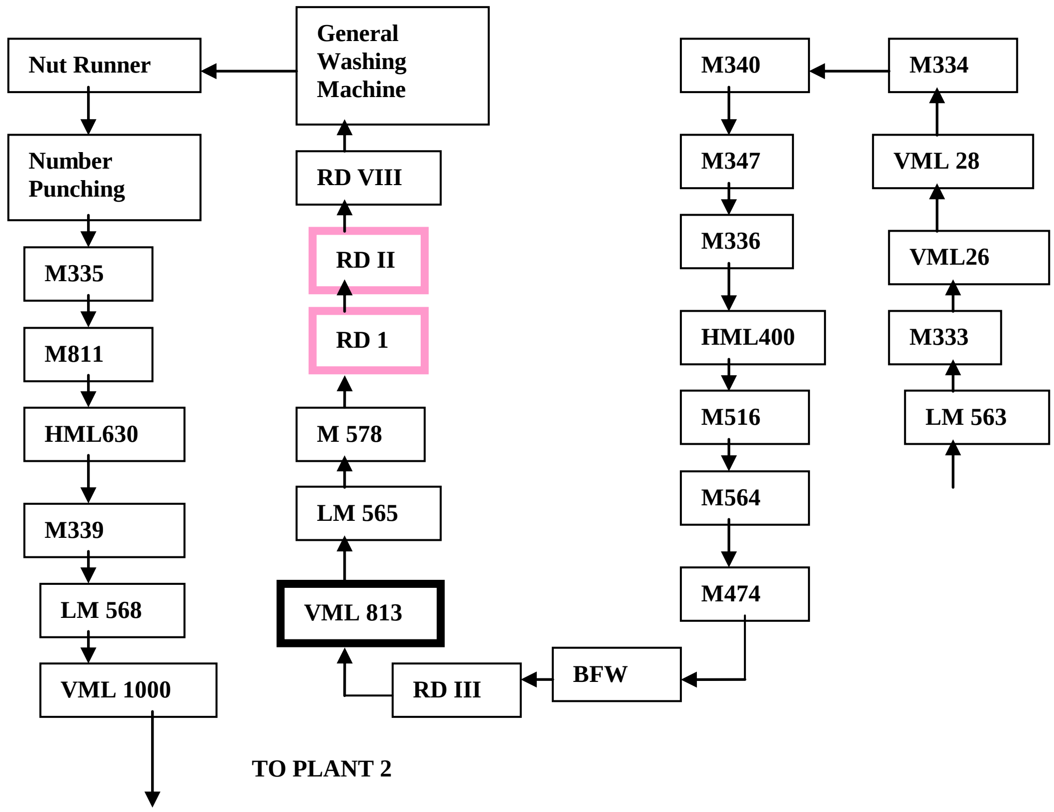
III. WHY WE USE LINE BALANCING?

All factories that have a line such as traditional assembly line and new assembly line such as heuristic and U-type and also mixed models in order to locate a machine, employer ,assign employer to machine to select best choose for control and work by machine . In a few company one employer control two or more than two machines and this result is out put of line balancing. In another word the company used line balancing for grow up the rate of produce and decrease man power, idle time and buffer near machine, also used line balancing for produced more than two products. Systematic approach can be developed which exactly fit these requirements, while decreasing the required flexibility to a minimum. Moreover, practitioners might be provided with valuable advices on how to use already existing models and procedures for their special assembly system

IV. STUDY APPROCH IN PLANT 1

A. We conducted study on plant layout 1 and it is displayed below.

Plant Layout 1 (Fig 3)



B. Plant Operations Descriptions

Sl. No.	Machine No.	Operation description
1.	M563	Mill average pads drill and ream 2 dowels on exhaust side
2.	M333	Head face and B-cap channel rough sump face milling
3.	VML-026	Finish mill, drilling of dowel holes and fixing holes on sump face
4.	VML-028	Pallet mounting dowel holes, oil pump mounting drilling and dowel on sump face and finish B-cap channel
5.	M334	Rough , finish mill rear and front face
6.	M340	Crank side, web milling and notch milling on crank
7.	M347	Drilling and reaming of 8 nos. dowel holes on the head face

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8.	M336	Fuel injection pump back face milling
9.	HML400	Rough and finish milling on sensor MTG pad, drilling of oil hole, drilling and champhering on front face and milling on exhaust side
10.	LM516	Main oil gallery drill hole on front side
11.	LM564	Two spindle semi finish barrel bores, boring and champhering
12.	LM474	Both sides face milling
13.	BFW	Oil filter pad milling
14.	RD – III	Drill crank and cam holes
15.	VML813	Barrel bore relieving and bottom champhering
16.	LM565	Drilling and reaming of holes on the head face
17.	LM518	Drill holes on exhaust side
18.	RD - I	Drilling on sump face
19.	RD – II	Drilling in bearing cap channel
20.	LFT - 08	Drill angular oil holes for crank and cam bore
21.	Washing machine - I	Cleaning of the cylinder block for removal of chips blocking the holes and passages
22.	LM335	Cylinder boring
23.	HML 630	Left over drilling on exhaust side, intake side spot face drilling, angular oil hole pad milling dipstick hole pad milling, no: punching pad milling and S2 oil hole drilling and tapping
24.	LM 339	Semi finish cam boring and rough cam boring
25.	LM 568	Angular holes drilling
26.	VML 1000	Back face drilling

After a careful analysis and the operation performed at each station, few problems were observed. The following are the list of problems, encountered or observed. There was no drastic need for any alteration of the layout. The stations set up, took up their allotted space. There was no space wastage or time wasted, in transportation of the component from one station to another. But there were problems encountered, after observing the operations performed at each station. The following were the problems, observed, after the analysis of plant I. Automatic Tool Changer in VML 813; - not functioning: In VML 813, this is a Vertical Type CNC .

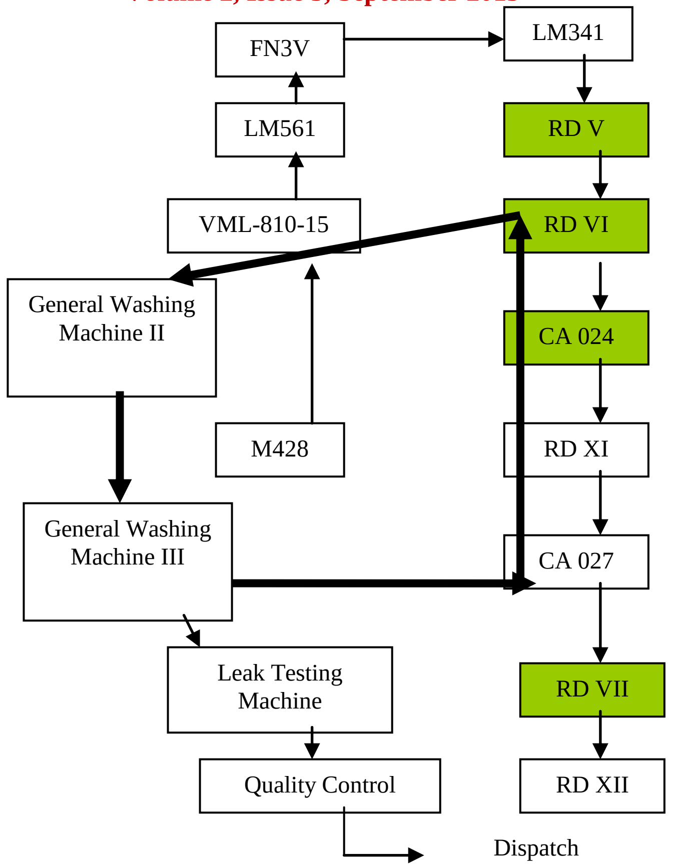
C. Observations and Analysis Report on Plant 1

- Machine, performing drilling and other operations, we noticed that the automatic tool changer was not functioning, and the tool for each operation had to be manually changed. This manual changing of the tool led to an increase in the time taken for the operations to be completed at that particular station. This increase in time, also affected the total cycle time of the component. VML 813 can be viewed in Annexure plant layout 1, highlighted in black.
- Combining two machines, performing the same operation: After a detailed analysis of all the operations performed by the machines, we observed, two machines, namely RD I and RD II, performed the same following operations, drilling of holes in sump face performed at RD I, and drilling of bearing cap channel, done at RD II. A suggestion was made to combine both the operations into one machine and both the operations be performed on that machine, thereby reducing a total of 2 workers and 67 seconds of time, spent on transporting, loading and unloading.

V. STUDY APPROCH IN PLANT 2

A. We conducted study on plant layout 2 as displayed below (See: Fig 4)

Plant layout 2 (Fig.4)



B. Plant Operations Descriptions

Sl. No.	Machine no.	Operation description
I.	M428	Barrel bore roughing operation and cavitations with bottom chamber
II.	VML 2	Tapping on head face
III.	VML 810-15	Tapping on head face
IV.	FN3V	Number punching pad milling on FIP flange
V.	LM341	Rear crank bore thrust face
VI.	RD-V	Champhering and finishing of holes on intake and exhaust side
VII.	RD-VI	Oil hole drill and tapping engine MTG drain plug, PSB MTG speed sensor, batter MTG, BS-4 MTG holes tapping on intake side
VIII.	RD- XII	Inclined oil hole drilling, counter boring & tapping on FIP flange and IB MTG holes. Clutch MTG holes tapping
IX.	Washing machine –II	Cleans the holes and flushes out the impurities in the channels and holes
X.	Washing machine –III	Cleans the whole engine from outside
XI.	Air leak tester	Checks leakages in the finished cylinder block

C. Observations and Analysis Report on Plant 2

1 Machining Error: Over a course of two months, after analyzing the final production batch data, we noticed that there were approximately 13 pieces of components, which were made unusable due to machining errors. The company itself keeps a limit of 27, out of a total of 5000 units. Now, on verifying the errors, and the machines the errors were caused in, we noticed that the machines, RD V, RD VI, CA 024, and RD VII were most responsible for the machining errors, i.e. an average of 7 units per month. The machines are highlighted in Green in Annexure plant layout 2(Fig. 4)

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2. Transportation Time: In plant II, we noticed that after the operations performed on the unit at station RD XII, the unit had to be transported to the General Washing Machine II. This transportation, had to be done around a line of stations, and through the means of 3 personnel, and on an average took a time of 600 seconds (10 minutes) for the transportation of 8 units, by means of a trolley. The transportation route is depicted by a thick black arrow in A plant layout 2 (Fig. 4)

D. Space Utilization:

One other important point noted, during the analysis of Plant II was the improper space utilization (Ref : Shop floor Photo) Towards the North-West corner of the Plant, existed a lot of empty space, which on proper utilization, would reduce the total transportation time of the component as well as reduce unnecessary manpower, as well as reduce operator fatigue. The space available in the North-West corner is shown in figure 5.

Shop floor photo (Fig 5)

E. Cycle Time Estimates

The cycle time recorded for the various operations performed on each face of the component were noted and were tabulated. Please refer to File “Cycle Time Estimates” for the cycle time for each operation, on each face.

VI. REMEDIES SUGGESTED BASED ON OUR STUDY AND THEIR STATUS

The problems we had noticed, and suggested remedies and reasons for them being accepted or not are listed below:

A. Combining Two Machines, Performing the Same Operation: Two machines, namely RD I and RD II, (refer to the red highlighted area in Plant I layout), performed the same operations, i.e. drilling of holes in sump face performed at RD I, and drilling of bearing cap channel, done at RD II. A suggestion was made, to combine the operations of both the stations, and complete it at one station. This would reduce the cycle time by about 54 seconds, i.e. time taken to transport it from one station to the other, and also loading and unloading time. Also, two workers could be reduced as one station is completely removed. This suggestion was not accepted. The reason for this suggestion not being accepted was that, when the operations were combined into one station, the total cycle time increased. Another reason was that, when the operations are being performed at this station, the total number of components waiting in queue increased, thereby resulting in starving of the machines after this machine.

B. **Replacement of Radial Drilling Machines (4 Nos.) With Vertical CNC Type Drilling Machines (2 Nos.):** In our analysis of the second plant, we noticed that a large number of machining errors, occurred in either one of the 4 radial drilling machines, in the plants. Now, the causes for this, could be, Operator fatigue, or the operator being indulged in unnecessary talk/ activities. We suggested replacement of the 4 radial drilling machines, with 2 Vertical CNC type Drilling machines, which can be programmed to perform the operations done by the 4 radial drilling machines. Now, on replacing the machines, we were able to reduce the total number of workers from 8 (i.e. 2 per radial drilling machine), to 3 (1 for each vertical CNC machine and 1 additional worker for misc work). So we were able to reduce the number of workers needed for the job by 5. Therefore, the daily wages paid to the workers too

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could be saved. On replacement, we assumed the number of machining errors, which occurred in between these stations, to reduce to 0, since CNC machines have high levels of accuracy and they perform the same operations uniformly, day in and day out. So, our suggestions of replacing the radial drilling machines with vertical CNC type drilling machines were accepted.

C. **Altering Current Plant Layout In Plant Number Ii**, we noticed that after the operations performed on the engine block, in station Radial Drilling XII (RD XII), were completed, it took an average of approximately 600 seconds, in transporting the engine block from the current station to the General Washing Machine II. Apart from a lot of time being wasted in transporting the engine block, in sets of 6, there was a lot of man power being wasted too. For each round of transporting, there was a need for two people to help load the trolley with the engine block units, and one person to push the trolley to the other station. So, a total of 3 people were needed to transport the engine block from one station to another.

D. **Having noticed that there was a lot of usable floor space,** we suggested a change in the alignment of the existing machinery, along with the replaced machines. The new layout, drastically reduces transportation time by a few hundred seconds, and also helped in reducing unwanted manpower. We figured that a change in alignment would reduce manpower by 2 numbers. We could have removed all three, but we made it a point to keep one worker, so as to help ease the transportation of the engine block through the roller-type conveyors.Having reduced the time taken for transportation and also reducing manpower, this suggestion too was accepted.

E. Automatic Tool Changer in VML 813: - Not Working in Plant I, on keen observation of each station, we noticed that the automatic tool changer on a vertical CNC type drilling machine was not in a working condition. Due the lack of a functioning Automatic Tool Changer (ATC), the tools had to be manually removed and inserted by the operator. In manual changing of the tool, the machine has to be stopped, followed by the unlocking of the chuck, which is done by a button, and then removal and then insertion of a tool, locking the chuck and then restarting the machine. This process thereby increased the time taken per engine block for the operations at that particular station to be completed. Since the Tool Changing was manually done, there was no consistent time. Now, the reasons responsible for an inconsistent time in completion of operations are because of Operator Fatigue, Indulgence in non-productive activities and boredom out of constantly performing the same task. We therefore requested the company to have the Automatic Tool Changer, replaced, if not repaired, in order to increase the productivity of the station. This suggestion too, was well received.

VII. RESULTS OBTAINED FROM ANALYSIS OF DATA COLLECTED

A. Reduction of Machining Error:

Total allowable machining errors, per month = 27 / 5000
Percentage allowable = 0.54%
Number of machining errors caused due to workers in radial drilling machine = 7
Percentage of errors caused by workers in radial drilling machine = 25.9%
Machining cost per engine block = Rs.2480
Number of engine blocks, made unusable due to machining errors = 7
Total loss, per month = 7 x 2480
= Rs.17, 360
Approximate loss, per year = 17, 360 x 12
= Rs.2, 08, 320

B. Total Time Reduction:

Replacement or Repair of Automatic Tool Changer:
Total process time in VML 813 = 76 seconds.

Table: Time taken by Operator

Reading Number	Time Taken (in seconds)
1	102
2	100
3	110
4	115
5	108
Average	107.6

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Total time taken by operator = 107.6 seconds (based on an avg. of 5 readings)
Average time taken by Automatic tool changer = 5 seconds per tool change
Total number of tool changes = 3
Average time taken by machine = 3 x 5 = 15 seconds
Average time taken by operator to change tool = 10.53 seconds per tool change
Total number of tool changes = 3
Average time taken = 3 x 10.53 = 31.6 seconds
Time wasted = 16.6 seconds per work piece.

C) Transportation Time

Time taken to transport material, in present layout = 600 seconds
Time taken to transport material, in suggested layout = 60 seconds (Max.)
Total time saved = 600 – 60 = 540 seconds.
Man power Reduced in Transporting material = 2
Total Salary Reduced in one year = 2 x 300 x 25 x 12 = Rs.1, 80,000

D. Total Cost Savings to the Company:

Total number of Workers reduced after replacement of Radial Drilling Machines with Vertical CNC type Machines; - 8 – 3 = 5
Salary per day per worker = Rs.300
Number of Working days in a month = 25
Total Salary reduced in one year = 5 x 300 x 25 x 12
= Rs.4, 50, 000
Man power Reduced in Transporting material, after altering layout = 2
Total Salary Reduced in one year = 2 x 300 x 25 x 12
= Rs.1, 80, 000
Total Loss averted, due to reduction in machining errors;
Machining cost per engine block = Rs.2480
Number of engine blocks, made unusable due to machining errors = 7
Total loss, per month = 7 x 2480
= Rs.17, 360
Approximate loss, per year = 17, 360 x 12
= Rs.2, 08, 320
Total Money Saved per year = Rs.4, 50, 000 + Rs.1, 80, 000 + Rs.2, 08, 320
= Rs.8, 38, 320

E. Payback Period:

Cost of Vertical CNC = Rs.40, 00, 000
Total cost = 40, 00, 000 x 2
= 80, 00, 000
Amount of money saved per annum = Rs.8, 38, 320
Payback period = 80, 00, 000 / 8, 38, 320
= 9.54 years.

VIII. CONCLUSION

At the end, the total operation time per component was reduced, which would hence contribute in a slight increase of the total number of components completed per month. Another aspect which was significantly reduced was the transportation time of the component from one station to another. This was mainly done by changing the plant layout. Once the plant layout was changed, the need for manual transportation was eliminated, which thereby also eliminated the need for manpower needed for transportation. After all the calculations, assessment and modification of the existing plant layout, the following points were concluded:

- The current cycle time is reduced, by 16.6 seconds.
- The transportation time is reduced, at least by 540 seconds.
- Unnecessary manpower is reduced, totally by 7.
- The total number of machining errors has been brought down to 0.
- Operator ergonomics is improved

IX. ACKNOWLEDGMENT

Mr. P. Vidyut Chandra would take this opportunity to thank the students for their efforts and time spent during gathering of data and information and also for their contribution during analysis until final results.

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AUTHOR BIOGRAPHY

*__P. Vidyut Chandra__ holds a Bachelors degree in Mechanical and Masters in Industrial Engineering and Management, Post Graduation in Operations Management; He is Ex Manager –TQM from Davangere cotton mills.. He worked as management consultant for over 12 years of which 6 years visiting Saudi Arabia and Oman and accumulated rich expertise with major focus on execution of projects related ISO 9001, Industrial engineering for Saudi industrial gas supply company and Almutlaq services at KSA

Professionally he is a qualified lead auditor for ISO 9001, Green Belt for Six Sigma Quality and Certified Quality Manager from Qimpro College –Mumbai. Presently as Assistant Professor in Sreenidhi Institute of science and technology with the Department of Mechanical Engineering, Specialized in teaching Production Planning and Control , with focus on lean manufacturing , Operations Research and Total Quality Management.

**__Siddhant Umesh Sawant:__
He is currently in his final year of his undergraduate studies, he is pursuing Mechanical engineering in Sreenidhi Institute of Science and Technology, Hyderabad, Andhra Pradesh. He is interested in production analogy and lean manufacturing system. He was an intern at Superpack machines where he was placed in the department of Design and Production.

**__Rahul Jacobi:__
He is currently in his final year of his undergraduate studies, he is pursuing Mechanical engineering in Sreenidhi Institute of Science and Technology, Hyderabad, Andhra Pradesh. His new found interest in line balancing has lead him to contribute to the research. He was an intern at Crompton greaves where he was placed in production department.

**__Nadir Sumiran:__
He is currently in his final year of his undergraduate studies, he is pursuing Mechanical engineering in Sreenidhi Institute of Science and Technology, Hyderabad, Andhra Pradesh. He is interested in line balancing and lean manufacturing system. He was an intern at Crompton greaves where he was placed in production department.

**__Medisetty Saicharan:__
He is currently in his final year of his undergraduate studies, he is pursuing Mechanical engineering in Sreenidhi Institute of Science and Technology, Hyderabad, Andhra Pradesh. He is interested in manufacturing processes. He was an intern at Superpack machines where he was placed in the department of Design and Production.