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Labour Productivity Improvement in an Automobile Component Manufacturer Machine Shop using Lean Tools

A.Pradeep, A.Manimaran, P.Arunkumar, K.Balaji

Abstract*: Productivity Improvement has become an important goal for today's automotive industry, as the customer demand is increasing every day. Organisation takes this as an opportunity to improve the business potential. Implementation of lean manufacturing tool results in productivity improvement and cost reduction in several companies. There is a strong correlation between productivity and labour productivity. Labour productivity improvement has a direct impact on business growth. This article presents a case study on application of lean manufacturing tool "Eliminate Combine Rearrange Simplify (ECRS)" in the manufacturing industry. This work is carried out in a medium scale automotive parts manufacturing company where all kinds of machining operation is taken place and the output of the product is supplied to vehicle manufacturer. This case study is illustrating increase in labour productivity in an automobile component machining line by applying the ECRS technique. Vertical Machining centre, Combination of tool, man and machine concept is used for implementing ECRS technique in the machining line. After implementation there is significant increase in labour productivity and reduction in throughput time and saving of space on the shop floor.

***Keywords* : Eliminate Combine Rearrange Simplify (ECRS), Vertical Machining Centre, Throughput Time, Labour Productivity.**

I. INTRODUCTION

Systematic management practices such as lean production promote improvements in productivity and reduce unnecessary waiting time during the manufacturing process and increase quality and speed. [1] Usage of latest technology for manufacturing will reduce the throughput time. Investment in production techniques have a positive effect on productivity through reduction of personnel expenses, increased outputs, reduced costs and increased flexibility. The technique of seeking improvement for increasing productivity by verifying the necessity of work elements is Eliminate Combine Rearrange and Simplify- ECRS. [2] Among these four principles the Combine technique has been used in frozen chicken producer to combine job A and B which reduces the manpower. [3] For productivity improvement in a drinking water production plant, equipment has been used to combine the product at the packing stage for the ease of putting film on the water bottle, which has reduced the cycle time and increased the productivity. [4] For manpower reduction in a pasteurized milk manufacturing organisation, job done by two workers was reduced to one. [5] Production rate has been improved in a horn assembly line by combining two machines performing pre and final crimping process in a single machine. [6] So far the combine technique has been used to combine two machines, two jobs and two operations.

Labour productivity is calculated to measure the efficiency of men. There is a high degree of correlation between labour productivity and business performance. [7] Labour productivity is the ratio of total production volume to the total number of labour. Based on the volume of production the type of machine to be installed is decided which in turn influences the plant layout. Proper utilization of factory floor space depends on the plant layout. Production quantity can be estimated by available working time in a shift. Available working time in a shift is calculated by subtracting various allowances from the total working time in a shift. These allowances are provided to compensate the worker for the production interruptions that may occur due to his personal legitimate needs or the factors beyond his control. [2] Shows that allowances such as Personal allowance 5 %; Fatigue allowance 5 %; and Delay allowance 5 %. As a total Personal Fatigue and Delay allowance - PFD comes to 15. The available working time is used to measure the takt time and cycle time. Cycle time varies from machine to machine. Machining centers are numerically controlled machines with multipurpose machining capabilities such as milling, drilling, boring, tapping, reaming, turning and grinding. Vertical machining centers have a vertical spindle where setup and handling are easier. This flexibility not only provides productivity improvements and throughput time reduction but also allows one machine to replace several single purpose machines or machining processes.

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***Correspondence Author(s)**
A.Pradeep, Department of Mechanical Engineering, Vel Tech Rangarjan Dr.Sagunthala R&D Institute of Science and Technology, Chennai., India. A.pradeep2005@gmail.com
A.Manimaran* Department of Mechanical Engineering, Vel Tech Rangarjan Dr.Sagunthala R&D Institute of Science and Technology, Chennai., India.. Email: mullaimaran@rediffmail.com
P.Arun Kumar, Department of Mechanical Engineering, Vel Tech Rangarjan Dr.Sagunthala R&D Institute of Science and Technology, Chennai., India. Email: arunkumarp@veltech.edu.in
K.Balaji, Department of Mechanical Engineering, Vel Tech Rangarjan Dr.Sagunthala R&D Institute of Science and Technology, Chennai., India. Email:kbalaji.me@gmail.com

Lean metrics like throughput time, cycle time and takt time are important when analysing and making decisions regarding a production system. Throughput time is the time a product takes to flow through the process, from start to finish. Cycle time is defined as the time taken to complete a task. Takt time is the ratio of available working time per shift to the customer's demand rate per shift. In this paper the combine technique is used to combine four machines in to a single machine, two operations were combined in to a single operations and two jobs performed by two operator were combined to single job operated by single operator for productivity improvement.

II. PROBLEM DESCRIPTION

In an automobile industry demand for front axle component is increased from 1600 units per month to 3300 units per month. The existing production capacity of front axle component per month is 1600 units by running single shift operations. Organisation decided to increase the production by running two shift operations by recruiting additional manpower to meet the demand which is a traditional method. But it increases the number of manpower and cost of production. There is no free space available in shop floor to buy any new machine to increase the production. The organisation wants to increase their profit through this opportunity. Hence it is suggested to apply combine technique to accomplish the task. Growth of an industry and its productivity ultimately depends on its ability to systematically and continuously respond to the market changes [8]

A. Problem Analysis

Front axle component produced in this organisation is a forging component which undergoes a series of 10 machining operations in 10 different machines to convert the raw material to finished component which is then assembled in a vehicle.

B. Production Planning

The organisation operation,

No of shift	: One
No of hours in a shift	: 8 hours
No of days in a week	: 5 days
No of days in a month	: 22 days.
Per month production	: 1600 units
Per day production	: 73 units (1600/22)

The following are the assumptions made for calculation,
There is no machine breakdown and no manpower absenteeism.

C. Existing Takt Time Calculation

The need of parts per day and the operating time of a shift in the production line defined by the organisation are essential to determine the takt time and the Cycle Time. [9] Production rate should be decided based on takt time. [10] 480 minutes are available in 8 hours shift time. While subtracting the lunch & tea break time and Personal needs Fatigue and Unavoidable delay (PFD) allowance, available working time for production is determined. Takt time is the ratio of available working time to demand. For a day,

Lunch break	: 45 minutes
Tea break/day (2x15) (15 minutes each)	: 30 minutes
Total working time/day (480 – (30+45))	: 405 minutes
Allowance for workers (405x0.15)	: 60.75 minutes
Available working time/day (405-60.75)	: 344.25 minutes
Takt time (344.25/73)	: 4.7 minutes

D. 3.3 Process Flow Diagram

Defining each process separately will help in implementing ECRS principle. [8] The study of process flow diagram would reveal the details of machining process, number of machines, types of machines, criticality of the process, preceding operation and number of stages in which the component undergoes machining process. There are 10 stages where all the machining operation like milling, drilling, boring, chamfering etc. are carried out as shown in Figure 1. 10 operations are mapped below. Each and every operation has preceding operations. Hence the problem in one operation affects the entire production line.

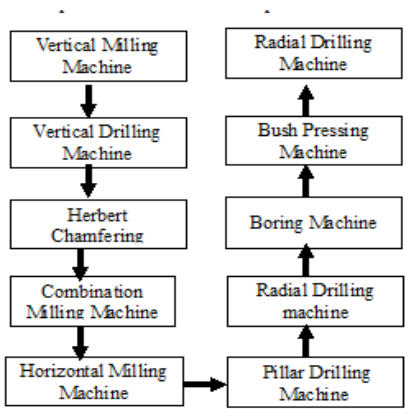

Figure 1.Process flow diagram for assembly line before implementation.

E. Machines Used for Operation

Each operation is carried out in a separate machine. All are single axis machines where only the y-axis movement is used for machining operation. These machines are called Special Purpose Machines (SPM). Machines are designed and tailor made for component specific requirements. Hence the machine used for one operation cannot be used for another operation or other component. All are unique. The entire production line with the series of machines are exclusively built for this front axle component.

F. Manpower Allocation

Manpower is allotted in each machine to produce the component. Each machine has one worker. Ten workers are assigned to ten machines. Every month there will be rotation of manpower between the machines in the same line.

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The term 'Lean' describes a production improvement strategy that expands on flexible manpower. [11] Average experience of each worker is 20 years. All the 10 workers have thorough knowledge about the component and its operation. Each worker assigned with a target production quantity of 73 units per day to meet the monthly demand of 1600 units. Organisation assesses their performance and the incentive is distributed based on the units produced by them.

G. Study of Existing Cycle Time

Cycle time of each operation varies considerably from component to component and operation to operation, creating an unbalanced process. [12] Cycle time measurement of production line used to identify the bottle neck area. There is no separate time allotted for inspection of component. While the machine (M/c) is running the operator inspect the finished component of last operation. Cycle time chart of front axle line is shown in Figure 2.

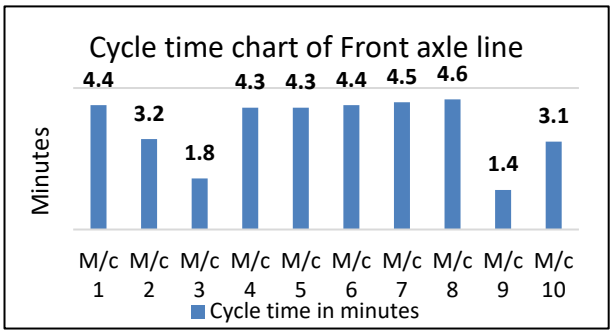

Figure 2.Cycle time chart of an assembly line before implementation.

III. METHODOLOGY

To increase the production in this front axle line from 1600 units to 3300 units, two techniques were discussed. Technique one is the organisation traditional method to increase the production by recruiting additional manpower for doubling the production volume. Drawback in this method is that it increases the cost of manpower and other cost. Hence it is suggested to use one of the ECRS techniques "Combine" to increase the production volume twice by operating two shifts without increasing manpower. It is done through, Combining the machines, Combining the operations and Combining the jobs

A. Combining the Machines

Investment in capital equipment has a major impact on output. [13] Automation has positive effect on throughput time. [2] Smaller and Easier operation carried out in a separate machine could be combined in one machine with multi operation facility. Hence many operations could be operated in a single machine to improve labour productivity. Thereby manpower will be reduced. All the existing machines are special purpose machines which cannot be used for other operation or multi operation as all are single axis machines. Hence for doing multiple operations, new machine is purchased which has three axis facilities for machining the component to cover many faces of component. Purchase of new machine and equipment to existing facility, adding a new shift to existing facility for getting maximum efficiency of resources. [2] As the operations are vertically performed vertical machining centre is used for multi operation with x, y and z axis. This machine operates with multiple tools and two pallets. When the component in one pallet is undergoing machining operation, we can unload the finished component from other pallet and load the new component. From the feasibility study, it is decided that the following operation can be combined using combine technique and put in multi operation machine,

Machine no. 1 : Vertical milling
Machine no. 4 : Combination drilling
Machine no. 5 : Horizontal milling
Machine no. 7 : Radial drilling

Combine technique is used to increase the productivity. [3] After combining all the four operations mentioned above in a new three axis machine the old four machines are removed from the line. Thereby the throughput time is reduced and it gives more free space in the line. Now the excess manpower available in the line could be utilised for other work.

B. Combining the Operations

Improvement in methods contributes to 30% of the productivity improvements. [2]The second, third, ninth and tenth operation has less cycle time compared to other machines. The second operation is drilling and third is chamfering. Using the combine technique these two operations are combined in to a single drilling machine by introducing a new combination cutting tool which can do both drilling and chamfering operations. Hence the chamfering machine is removed from the shop floor. By combining two operations, the total cycle time should be 5 minutes theoretically. But the loading and unloading time is eliminated for chamfering operation and therefore the total cycle time becomes 4.4 minutes. Thereby the throughput time is also reduced.

C. Combining the Job

Man Machine chart is used to minimise man or machine idle time. Line balancing methods attempt to allocate equal amounts of time for each worker. [5] Cycle time chart shows that the ninth and tenth operation has less cycle time compared to takt time. Both the machines are operated by separate worker. Using the combine technique, ninth and tenth operations are combined as one job. One worker operates both the machines by still maintaining the cycle time within the takt time. The total cycle time taken by machine number 9 and 10 is 4.5 minutes. Combining ninth and tenth operation in to one job will not affect the production flow. By doing so there is elimination of one manpower.

D. Study of New Process Flow Diagram

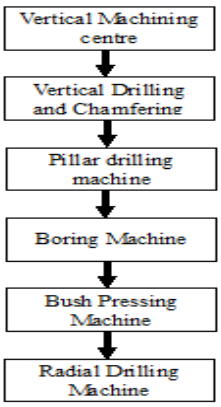

Figure 3.Process flow diagram of an assembly line after implementation.

Now the process becomes lean by eliminating six machines as shown in Figure 3.

E. Study of New Cycle Time

To check improvement to the process, cycle time before and after should be compared. [4] The cycle time of new three axis machine is 4.6 minutes. Within the specified cycle time four operations are completed. Second and third machines are combined and placed as a second machine in the machining line. Cycle time chart of new front axle line is shown in Figure 4.

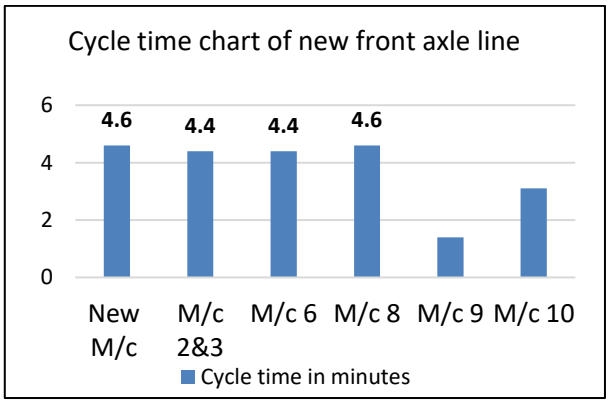

Figure 4.Cycle time chart of an assembly line after implementation.

The above bar graph indicates that the cycle time is uniformly distributed between the machines. The machining line is perfectly balanced. Hence there is no loss.

F. New Production Planning

Its need to take the maximum cycle time of 4.6 minutes for calculation of production volume.

Cycle time per component	: 4.6 minutes
Available time per shift	: 344.25 minutes
Production per shift (344.25/4.6)	: 75 no's
Two shift production (3300/22)	: 150 no's
Per month production (150x22)	: 3300 no's

Two shift operations to meet the monthly production requirement.

G. Productivity

Labour utilisation contributes to 30% of the productivity improvements.Productivity is a measure of output to input. Labour productivity is the ratio of production quantity to the number of workers. Organisation traditional method to increase the production from 1600 units to 3300 units is by doubling the manpower. Then the total manpower becomes 20 persons. The Labour productivity per day (150/20) would be 7.5. After applying the combine technique, two shifts is operated with 5 person per shift. Hence the labour productivity per day (150/10) is 15. Productivity of workers can be increased by adopting combine technique. [5]

H. Throughput Time

Speed of the production line is achieved by working on throughput time. [2] The total cycle time of four old single axis machines are 17.5 minutes whereas the new three axis machine is 4.6 minutes by doing the same operations. The improvement is a reduction of 12.9 minutes through the combine technique. It is because of the machine design, capacity and high feed and speed of the three axis machine. Also the loading and unloading for four times is avoided. So the time is saved significantly. The total cycle time of second and third machine is 5 minutes which is reduced to 4.4 minutes by combining it. In traditional method, the throughput time of whole front axle line with 10 machines is 36 minutes and while applying Combine technique the throughput time of front axle line with six machines is 22.5 minutes which is derived by adding the cycle time of all the six machines. Reduction in the throughput time reduces the variable cost to the organisation.

I. Man Hours

Workforce allocations directly influence the man-hour which is not only the unit of cost measurement but also main basis for organization planning and scheduling.

The number of operator per shift	: 5 no's
Shift hours	: 8 hours
Man hours per shift (5x8)	: 40 hours
No of shift in a day	: 2 shift
Man hours per day (40x2)	: 80 hours
Man hours per month (80x22)	: 1760 hrs.

As per the organisation traditional method, man hours per month would be 3520 hours (20x8x22) with 10 persons per shift. By applying combine technique man hours per month is 1760 hours with 5 persons per shift.

J. Cost of Machines

Modern technological developments decrease the market prices of newer assets as well as their salvage values and operating expenses. The replacement time for current assets in use should be reassessed to reflect this decrease. Since here removed five machines which is five year old machine and added one new machine, cost is calculated to ascertain profit or loss.

Cost of SPM drilling machine : 20 Lakhs
Cost of SPM Chamfering machine : 15 Lakhs
Cost of SPM Milling machine : 55 Lakhs
Cost of one SPM drilling, one SPM Chamfering and three SPM Milling machine ((20+15) + (55x3)) : 2 Crores
Depreciation cost for five year old five machine @ 10% per year (200x0.1x5) : 1 Crore
Cost of new VMC machine : 80 Lakhs
From the above data, it is profitable to buy a new machine.

K. Space Occupied

The space occupied by removing five old SPM machine and installing one new VMC machine is calculated. Space occupied by one SPM machine is 13.2 Sq. The space occupied by ten SPM machines are 132 Sq. m. One VMC machine occupies the space of two SPM Machines. So the space occupied for new front axle line with six machines are 92.4 sq. m. Area saved is 39.6 sq. m.

L. Power Consumption

Power consumption of any machine is gauged on the consumption of energy in kilowatt. Power consumption of each special purpose machine is 7.5 KW. As per the organisation traditional method, the total power consumption of 10 special purpose machines is 74.6 KW. The power consumption by the new vertical machining centre is 37.3 KW. As per the Combine technique, the total power consumption of new 6 machines in the line is 74.6 KW. Since there is no increase or decrease in the power consumption after implementation, the new machine can used for productivity improvement.

IV. RESULT AND DISCUSSION

From the organisation production data, per day production quantity was calculated to increase the production because of the increase in customer requirement. While going through the process flow diagram, it is observed that 10 machines in a line are used to convert a raw material to a finished product. Each machine is operated by a separate operator. Every minor machining operation is carried out in a separate machine which increases the usage of manpower, shop floor space and throughput time of the line. All special purpose machines are designed for specific machining operations. Hence studied the takt time, cycle time and criticality in the machining operation.

To increase labour productivity, the six operations like milling, drilling, counter boring, combination milling, horizontal milling and radial drilling were combined in a new single multi operation machine i.e. Vertical Machining Centre. But the cycle time is increased from 4.6 minutes to 7 minutes for this newly introduced machine and the production volume has been reduced from 75 units to 50 units per shift. This bottleneck machine decides the production capacity of the line. Then only four operations like Milling, combination milling, horizontal milling and radial drilling are combined in a Vertical Machining Centre. Therefore the cycle time of this new machine is reduced to 4.6 minutes which is within the takt time. Thereby there is a reduction in number of machines, man hours and shop floor space. Instead of operating two shifts with additional manpower to meet customer demand, applying combine techniques in a machining line avoids the additional manpower requirement to meet the customer demand of 150 units per day.

Table-I Comparison of results with Traditional system

	Traditional method	ECRS technique
Description	10 Machines	5 Machines
No of Shift	Two shifts	Two shifts
Production per shift	73 units	75 units
Labour productivity	7.5	15
Throughput time	36 minutes	22.5 minutes
Man hours	3520 hours	1760 hours
Space occupied	132 Sq. m	92.4 Sq. m
Power consumption	74.6 KW	74.6 KW

To summarise, the comparison of traditional method and ECRS technique is shown in table I, to study the effect of production parameters for producing 150 units of component per day.

V. CONCLUSION

Lean manufacturing is an effective tool to increase productivity in manufacturing industry. Implementation of lean manufacturing tool ECRS improves the efficiency and reduces the waste. Combine technique is applied and achieved 100% increase in labour productivity. Comparing the results achieved in this case study between traditional method and ECRS method on six parameters shows that applying ECRS technique gives best result. Application of the combine technique reduces the waste by combining the aspects of machines, operations and job. By combining the operations we save shop floor space which can be used for future expansion work. Reduction in manpower gives way for better utilisation. As the scrap value of the old five machines is used for purchase of new vertical machining centre, there is no additional investment cost. This ECRS Combine technique is applicable for all automobile component manufacturers who are doing machining operation. Hence the action taken in this case study can be applied for the benefit of the organisation. This ECRS approach is more valuable for researchers working in lean manufacturing area to take it forward.

The future work can be carried out by further combining the machining operations through single machining centre could lead to enhance the productivity.

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AUTHORS PROFILE

A. Pradeep, Masters in Automobile Engineering and currently working in Automobile sector. He is pursuing his research in lean tools and techniques.

Dr. A. Manimaran Professor, Department of Mechanical Engineering, Vel Tech , Avadi Chennai. Has done his Ph.d in cellular manufacturing and published many papers in the area of lean manufacturing. He guided many PG and Ph.d students. He is a Lean six sigma green belt and his area of interest is Lean six sigma. He received fund various funding agencies

P.Arun Kumar Assistant Professor, Mechanical Engineering, Vel Tech , Avadi Chennai. Has done his Masters in lean manufacturing and also a Lean six sigma green belt.

Dr.K.Balaji Assistant Professor, Mechanical Engineering, Vel Tech , Avadi Chennai. Has done his Ph.d in Lean manufacturing and published many papers in the area of lean manufacturing. He guided many PG and Ph.d projects.