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Productivity Measurement and Improvement in Manufacturing Firms by Improving Assembly Line

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Abstract

The paper deals with case study for improving production efficiency of one off manufacturing firm, which have been providing quality sheet metal Air Coolers to the customers, but still it suffers from lack of effective Plant layout, and has improper sequencing of processes. Thus there is wide scope of improvement for enhancing the productivity. Hence to remove the flaws the study of processes is done that are involved in manufacturing and assembly of parts of coolers. The need of this study is streamlining of processes and proposing the changes in the present process to standardize operations and design.The work deals with the study of steps involved in manufacturing of each part, which helps to get design of parts and designing Process Flow Diagram. From the Process Flow Diagram, Standard Operating Procedure can be obtained. The operators are performing the operations according to their estimation, but now the SOP will help them to follow the particular sequence of steps. Various parameters and machines used are studied. The study helps to identify manual and machinery operations.The work involve the use of AUTOCAD software of two dimensional drawings of parts.The study deals with designing the present plant layout and obtaining the new plant layout by the proposing changes to improve productivity. The present plant layout needed to be changed because it cause blocking of operation . Operation are not able to perform various operations simultaneously. Also the process have become complex and timing consuming.The modified plant layout gives proper sequence of process.According to the study the four different variants of coolers available and founded their dimensions. Indentification that there is no standardization for the process has been made.The operators are unable to keep the dimensions contant in all the parts for the different coolers of the same model.Moreover, for different model the dimensions of all the parts varies with the other models.Obeservation that within different models only the size of fan and so the size of front called a circle should vary ,keeping the dimensions of all the other parts as constant within all the models has been made.this can reduce the unnecessary utilization of sheet metal and thus saves time and enhance the productivity.Based on all the observations changes *were proposed to improve productivity.The AS-IS and TO-BE Analysis is performed,which includes transformation of processes as it is performed today towards a new processes that addresses problems with AS-IS analysis. The present research focuses on measuring and improving productivity in manufacturing firms through a structured approach. The study adopts a systematic methodology, including the identification of productivity indices, data collection from selected firms, and analysis using performance ratios. The productivity measures considered include labor productivity, machine productivity, material productivity, and rejection rates. These indices help identify existing inefficiencies and provide quantitative insights into resource utilization*

Key words: *Time study, AutoCad, plant layout, Quality.*

1. Introduction

The Air Coolers manufactures and supplies Desert Air Coolers made of sheet metal. The company started functioning with an objective of providing excellent products to its valuable clients and to provide its customers the highest quality of sheet metal air coolers. It uses energy efficient technology to bring fresh air into our home or office with zero impact on the ozone layer, helping to reduce the greenhouse effect. The parts are designed so as to assist Evaporative Air cooling. Evaporative Air cooling is a physical phenomenon in which evaporation of a liquid, typically into surrounding air, cools an object or a liquid in contact with it. The sheet metal is light in weight and so it is easy to move coolers from one place to another. The company manufactures four types of models and uses different processes for each type of model. This study changes in plant layout and streamlined the processes by obtaining process flow diagrams and then drives standard operation procedures from them. The design related issues by obtaining the present designs of all the parts. Objective of this study is enhancement of productivity of plant by:

- Improvement in assembly line efficiency.
- Streamlining of assembly line
- Improving labour productivity

2. Literature Review

Plant Layout is an arrangement of facilities and services in the plant. It outlines relationship between production centers and departments. Plant layout can be defined as an optimum arrangement of industrial facilities, including personnel, equipments, storage space, material handling equipments and all other supporting services, in an existing or proposed plants. Plants Layout can also be defined as: "A technique of locating machines, processes and plant services within the factory in order to secure the greatest possible output of high quality at the lowest possible total cost of production." Studies have shown that productivity measurement in manufacturing requires a balanced evaluation of labor, machine, material, and energy utilization.

- **Labor Productivity**: Sumanth (1994) defined labor productivity as output per labor hour, highlighting its significance in labor-intensive industries. In automobile manufacturing, work specialization, skill development, and workforce motivation play key roles (Kumar & Singh, 2016).

- **Machine Productivity**: Machine efficiency depends on maintenance, setup time, and utilization rates. Nakajima (1988) introduced **Total Productive Maintenance (TPM)** to improve machine reliability and reduce downtime.
- **Material Productivity**: Womack et al. (1990) highlighted that waste reduction in material handling is a core principle of **Lean Manufacturing**. Material productivity is closely linked to supply chain efficiency and inventory management (Rajesh & Venkataraman, 2017).
- **Multi-Factor Productivity (MFP)**: Several researchers (Jorgenson, 1995; Hulten, 2001) emphasized measuring productivity as a function of combined inputs rather than individual ratios, enabling a holistic evaluation.

2.1 Lean Manufacturing

Lean principles, introduced by Toyota Production System (TPS), emphasize waste reduction, Just-in-Time (JIT) production, and continuous improvement (Kaizen). Studies (Shah & Ward, 2003; Bhasin & Burcher, 2006) demonstrated significant productivity improvements through Lean implementation in automobile firms worldwide.

2.2 Total Productive Maintenance (TPM)

TPM, introduced by Nakajima (1988), aims to maximize equipment effectiveness by minimizing breakdowns, setup losses, and speed losses. Research by Ahuja and Khamba (2008) indicated that TPM improves Overall Equipment Effectiveness (OEE), leading to higher machine productivity in automobile plants.

2.3 Six Sigma and Quality Improvement

Six Sigma has been widely applied to reduce variation and defects. Harry and Schroeder (2000) highlighted its role in improving process capability. Automobile firms have integrated Six Sigma with Lean, resulting in **Lean Six Sigma** for both productivity and quality improvements.

2.4 Supply Chain and Material Management

Christopher (2011) emphasized that productivity is linked to supply chain responsiveness. Efficient logistics, supplier collaboration, and JIT delivery systems improve material productivity and reduce wastage in automobile manufacturing.

2.5 Industry 4.0 and Automation

Recent literature highlights the growing adoption of **Industry 4.0 technologies**—including IoT, Artificial Intelligence, robotics, and predictive analytics—to enhance productivity. Hermann et al. (2016) described Industry 4.0 as a paradigm shift enabling real-time monitoring and decision-making. Research by Sony and Naik (2019) showed that digitalization improves efficiency, quality, and flexibility in automobile manufacturing.

3. Problem formulation

Problem is inefficient present layout and poor material handling which can be reduce by designing Process Flow Diagram,selective inventory control and Standard Operating Procedure.

Problems in present layout

Delays in material moving, Cross Traffic, Long Hauls, Manual Handaling,Inadequate Handling Equipment, Unbalanced Sequence Of Operation ,Obstacles to Material flow ,Material piled directly on floor, Cluttered aisles ,Cluttered work space, Backtracking of materials ,Long travel distance ,Improper communication ,Lack of supervision, Inadequate workforce

3.1Methodology

There are four different models available in the company, but any part of all the models goes through the same procedure. So single model is focused i.e. Model with grill size 18".The procedure used for this Model can be referred for other ones also.

3.2 Developing the proposed layout

Plant Layout is an arrangement of facilities and services in the plant. It outlines relationship between production centers and departments. Plant layout can be defined as an optimum arrangement of industrial facilities, including personnel, equipments, storage space, material handling equipments and all other supporting services, in existing or proposed plants. Plants Layout can also be defined as: "A technique of locating machines, processes and plant services within the factory in order to secure the greatest possible output of high quality at the lowest possible total cost of production."The paper deals with the study of Flow, storage, transportation, delay and operation of all the parts of 18 inch model. From this, information about other models can be obtained. As only dimensions are changing and other parameters keeping intact so the recommendations for the studied model are also applicable for other models as well.

3.3 Problem Identification:

Material handling ,Random storage ,Manual material transfer ,Lack of space ,Improper communication ,Assemly line ,Frequent Pauses ,Lack of supervision ,No provision for handling tools ,Lack of workforce ,Delay in delivery of parts

3.4 Techniques used for giving recommendations

During the research work, the following techniques for giving recommendations were used:

a) Dimensional plan of the space layout.
b) Description of the operations and sequences.
c) Volume of work to be taken from the space at present and in future.
d) Amount of material, buffer stock required at each work station.
e) Size of finished and semi finished product inventory.

4. Case Study: Data Collection and Analysis

Air Coolers manufacturing unitwas established in the year 1980.They emerged as one of the leaders in manufacturing desert air coolers in central india and have been providing quality products to its customers for over 25 years.It emerged as the market leader in the manufacturing and supplying of desert air coolers .Its objective is providing excellent products to its valuable clients and to provide its customer the highest quality of sheet metal air coolers at most competitive prices.

With more than two decades experience in this sphere of business,the company has sat benchmarks of quality.Ananad air cooler uses energy efficient technology to bring fresh air into your room ot office with zero impact on the ozone layer, helping to reduce the green house effect.They have consistently perform to achieve astounding success in the production of different types of air coolers .And have adapted quickly to changes in the market and constantly adding new products to range, as well as making improvement to existing range. The company manufacture evaporative air coolers.Evaporative cooler (or air cooler) are devices that cool air through the simple evaporation of water.They differ from refrigeration or absorption air conditioning, which use vapor compression or absorption, refrigeration cycles. Evaporative cooling is especially well suited for climates where the air is hot and humidity is low.

In dry climates, the installation amnd operatoing cost of an evaporative cooler can be much lower than refrigative air conditioning.They are known in the market not only for wide array of product that they manufacture but also for gaining name and fame with their high standards.They follow the right blend of hardwork and innovative thinking,to generate products that have a universal appeal.They have consinatnly performed to achieve astounding success in the production of different types of air product and have adaptive quickly changes in market and are constanly adding new product range,as well as making improvement to existing range.Today Anand air cooler is symbol of innovative excellence and has responded to varied stated and implied needs of customers in terms of quality,cost and delivery

With more than two decades experience in this sphere of business, the company has set benchmarks of quality. They are familiar with the requirement of clients, which enables us to manufactures products of high standard and within the stipulated time period.

Since there inceptions in this business, there main objective of manufacturing such product has been to fulfill there patron's requirement. The whole range product offered by Anand is a benchmark for there quality standard and innovative designs.with the innovative and exclusive solutions, they marked a place for them in this competitive market.

Table 4.1: Time study chart

S.No	Operation	No. of operators	Observation 1			Observation 2			Observation 3			Average Time
			Start Time	End Time	Cycle Time	Start Time	End Time	Cycle Time	Start Time	End Time	Cycle Time	
1	Front and Tank fitment	2	0	151	151	151	325	174	325	531	206	177
2	Pump fitment	1	0	50	50	50	105	55	105	158	53	52.67
3	Motor and Damper Fitment	1	0	52	52	52	101	49	101	156	55	52
4	Motor fitment	2	0	100	100	100	211	111	211	365	154	121.67
5	Frame fitment	1	0	100	100	100	220	120	220	335	115	111.67
6	Pump and Motor Wiring	1	0	150	150	150	330	180	330	530	200	176.67
7	Control panel fitment	1	0	470	470	470	960	490	960	1480	520	493.33
8	Column fitment	1	0	188	188	188	408	220	408	638	230	212.67
9	Tray fitment	1	0	150	150	150	305	155	305	457	152	152.33
10	Water Distributer Fitment	1	0	10	10	10	25	15	25	37	12	12.33
11	Pipe Measurement and Cutting	1	0	24	24	24	52	28	52	82	30	27.33
12	Pipe Attachment	1	0	15	15	15	33	18	33	47	14	15.67
13	Fan fitment	2	0	55	55	55	120	65	120	186	66	62
14	Looers fitment	1	0	220	220	220	480	260	480	760	280	253.33
15	Side panel fitment	2	0	30	30	30	65	35	65	97	32	32.33
16	Back panel fitment	1	0	32	32	32	62	30	62	97	35	32.33
17	Lid	1	0	10	10	10	20	10	20	30	10	10
											Total	31995.33

Standard time calculations:
Assuming Rating to be 80% for semi skilled worker
Normal time = Observed time * Rating
Normal time = 37.37*0.80 min
Normal time = 29.9 min
Taking allowance = 4%
Standard time = Normal time + allowances
Standard time = 29.9 + (29.9*0.04)
Standard time = 31.1 min =0.518 hrs
Average time for assembling 1 cooler from table:
Average time = 1995.33/ 60 min
Averagetime=33.255min.

Table 4.2: Standard Time Calculations

S.No	Activity	Time (Hours)
1	Total time for 1 cooler according to existing plan	.554
2	Time taken for 1 cooler without delay(std.time)	.519
3	Total delay in one cooler	.35
4	Total delay in batch of 16 coolers	.57
5	Total time in manufacturing 16 coolers according to standard time	8.3
6	No.of coolers that can be made by reducing delay	(8.3+5.7)/5.2=17
7	Total time taken to manufacture 16 coollers accc,to std.time	8.87
8	Reduced delay	9-8.87=1.3

In this way assembly of one cooler can be done per day by reducing delay

5. Result and Discussions

This paper used Nadler's Ideal System Approach in which it is believed that it is important to focus initially on "what can be" instead "of what has been". New designs of plant layout have been proposed and the increase in productivity before and after implementation of proposed plant layout is to be measured. Layout Implementation involve long term strategic decision making and once implemented it can't be changed for years.Moreover, layout changing is associated with large investments thus while doing this project, it was not possible to implement proposed layout in such a short span of time. Due to this it was not possible to measure change in productivity before and after implementation. But majority of problems causing inefficiencies in present layout such as back tracking of material, long travel distances, cross traffic, obstacles to material flow, etc.were handled.Moreover Process Flow Diagram has been developed which further helped to prepare Standard Operating Procedure. Process Flow Diagram is important for engineers and operators to find it hard to understand . Thus Standard Operating procedure is prepared using data obtained from PFD. Standard Operating Procedure are prepared for each and

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every single operation and they are displayed on each workstation so that operator can refer it.While performing the operation Standrd Operating Procedure eliminates state of confusion and uncertainty among operators relating to operations. Anand coolers can have process Failure Mode Analysis and Assembly operation sheet by referring to PFD and SOP made under this project. There is no tangible value of result as there is no quantitative work involvedin this project. Result in the form of data sheets, PFD, SOP sheets ca be obtained and evaluated for errors. But it is assured that work done under this project will improve productivity of plant.

Proposed Changes in Layout

- Shifting of machines so as to make smooth and continuous flow of material.
- Arranging machine and manual operations towards the direction of assembly area, so that backtracking can be avoided.
- Introduction of doors for the sequential flow of materials.
- Making storage areas at appropriate places to avoid material piling on the shop floor.
- Centralization of Inventory.
- Provision of Racks & Trolley for material storage and handling.
- Using different doors for incoming and outgoing materials.

Daily Production Report

In almost all of the leading companies and firms, daily production report template is prepared, which show the number of task, quantity of work and time spent over work. The senior executive or project manager prepares the production report daily to keep other concerned people and higher authorities informed on the progress of the production and work. The project manager checks the pace of work and decides what they should do to increase pace of work. The production reports are different according to nature of work and comply with instructions of the department.

Labor Productivity Calculation

Labor Productivity=Total Output (Units)/Total Labor Hours

- Output (Monthly) = 12,000 units
- Total Labor Hours = 3,000 hours

Labor Productivity = 12,000 ÷ 3,000 = 4 units per labor hour

Machine Productivity Calculation

Machine Productivity=Total Output (Units)/Machine Hours Available

- Output (Monthly) = 12,000 units
- Machine Hours Available = 2,500 hours

Machine Productivity = 12,000 ÷ 2,500 = 4.8 units per machine hour

Material Productivity Calculation

Material Productivity=Output (Units)/Raw Material Used (Kg)

- Output = 12,000 units
- Raw Material Consumed = 9,000 Kg

Material Productivity = 12,000 ÷ 9,000 = 1.33 units per Kg

Rejection Rate Calculation

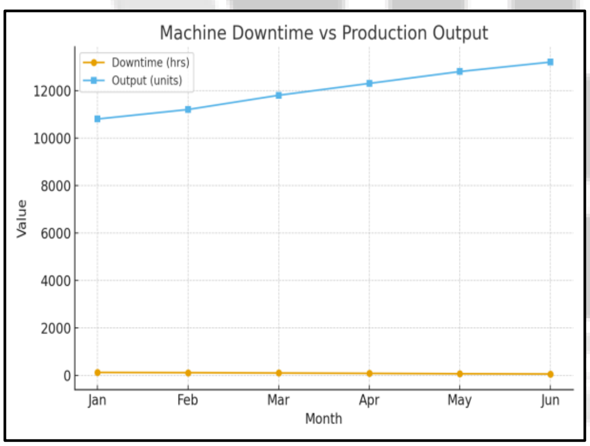
Rejection Rate=Defective Units/Total Output ×100

- Defective Units = 300
- Total Output = 12,000

Rejection Rate = (300 ÷ 12,000) × 100 = 2.5%

Table 5.1: Improvement parameters calculations

S.No	Parameter	Before Improvement	After Improvement	%change
1	Labor Productivity (Units/hr)	4.0	5.2	+30%
2	Labor Productivity (Units/hr)	4.8	6.1	+27%
3	Labor Productivity (Units/hr)	1.33	1.50	+13%
4	Labor Productivity (Units/hr)	2.5	1.2	–52%



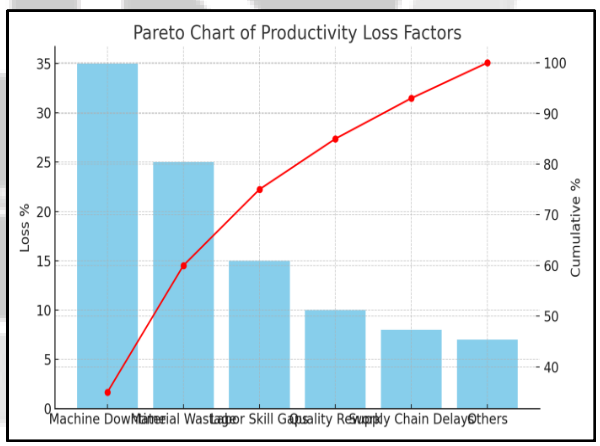


Figure 5.1: Productivity Loss Factors

Figure 5.2: Machine Downtime-Production Output

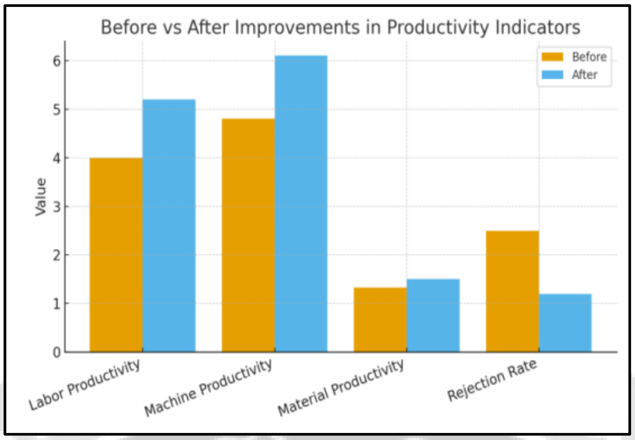


Figure 5.3:Productivity Improvement

References

- Ahuja, I. P. S., &Khamba, J. S. (2008). Total productive maintenance: literature review and directions. *International Journal of Quality & Reliability Management, 25*(7), 709–756. https://doi.org/10.1108/02656710810890890
- Bhasin, S., & Burcher, P. (2006). Lean viewed as a philosophy. *Journal of Manufacturing Technology Management*, *17*(1), 56–72. https://doi.org/10.1108/17410380610639506
- Christopher, M. (2011). *Logistics and Supply Chain Management* (4th ed.). Pearson Education.
- Gupta, R., & Sharma, A. (2020). Lean implementation challenges in Indian automotive industry. *Journal of Manufacturing Technology Management, 31*(6), 1105–1122. https://doi.org/10.1108/JMTM-07-2019-0264
- Harry, M., & Schroeder, R. (2000). *Six Sigma: The breakthrough management strategy revolutionizing the world's top corporations*. Doubleday.
- Hermann, M., Pentek, T., & Otto, B. (2016). Design principles for Industrie 4.0 scenarios. *2016 49th Hawaii International Conference on System Sciences (HICSS)*, 3928–3937. IEEE. https://doi.org/10.1109/HICSS.2016.488
- Hulten, C. R. (2001). Total factor productivity: A short biography. In C. R. Hulten, E. R. Dean, & M. J. Harper (Eds.), *New developments in productivity analysis* (pp. 1–47). University of Chicago Press.
- Jorgenson, D. W. (1995). *Productivity: International comparisons of economic growth*. MIT Press.
- Kendrick, J. W. (1961). *Productivity trends in the United States*. Princeton University Press.
- Kumar, R., & Singh, M. (2016). Analysis of productivity improvement in automobile industry. *International Journal of Engineering Research and Applications*, *6*(3), 12–19.
- Nakajima, S. (1988). *Introduction to Total Productive Maintenance (TPM)*. Productivity Press.

- Patel, V., & Desai, D. (2018). Productivity improvement through lean tools in Indian automotive sector. *International Journal of Lean Six Sigma*, *9*(2), 240–262. https://doi.org/10.1108/IJLSS-02-2017-0015
- Rajesh, R., & Venkataraman, R. (2017). A study on material productivity in Indian automobile industry. *International Journal of Production Research*, *55*(3), 715–729. https://doi.org/10.1080/00207543.2016.1196441
- Shah, R., & Ward, P. T. (2003). Lean manufacturing: context, practice bundles, and performance. *Journal of Operations Management*, *21*(2), 129–149. https://doi.org/10.1016/S0272-6963(02)00108-0
- Sink, D. S., & Tuttle, T. C. (1989). *Planning and measurement in your organization of the future*. Industrial Engineering and Management Press.
- Sony, M., & Naik, S. (2019). Key ingredients for evaluating Industry 4.0 readiness for organizations: a literature review. *Benchmarking: An International Journal*, *27*(7), 2213–2232. https://doi.org/10.1108/BIJ-09-2018-0284
- Sumanth, D. J. (1994). *Productivity engineering and management*. McGraw-Hill.
- Womack, J. P., Jones, D. T., & Roos, D. (1990). *The machine that changed the world: The story of lean production*. Harper Business.