Implementing Positive Lean Manufacturing in Automotive Industry: A Case Study

By

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Abstract

In the current competitive economic environment, the survival of industries in the global market can only be possible if production is done with high quality and minimum cost. The human factor is the main component of lean manufacturing, the knowledge of workers and management staff affects the success rate of implementation of lean. Low quality and high price products are the main obstacles of the organization. This study helps to understand the importance of human elements in which the implementation of lean manufacturing in the organization involves lower-level workers which have been more helpful to make the organization productive. Observed the previous layouts and find the flaws and gaps in the manufacturing process, layouts and pre-decision process that how much human factor involved in the current situation. Layout improvements, WIP concept, JIT, Time and Motion study were implemented with help of human factor involvement on every stage of the pre-decision process through the motivation of workers, defining the responsibilities and duties of the workers and standardized the work through process flow, detail and assembly drawings, quality checks and production record and analysis had done on available data with the use of the Quasi-Experiment method. The data had been gathered before and after implementing these techniques with the help of workers and management staff.

The MATLAB software was used to create the Plotting cool graph for better data manipulated and explained the difference. After implementation of these techniques 30% and 40.7 % manpower were reduced in the Water Bowzer and Fire Fighting vehicle project respectively. Implementation of JIT and WIP Concept with the involvement of human factor the rollout time is reduced to 34% in Water Bowzer and 85% in Fire Fighting vehicle project.

Keywords: Human elements, layout improvements, WIP concept, JIT, time and motion study, quasi-experiment method

Dedication

I would like to dedicate to my work to Almighty Allah and my parents. Allah gives me success more and more with never ended blessings. I dedicate this work and give special thanks to my beloved brother Muhammad Ilyas, Imtiaz Ahmad and my teacher Dr. Sheikh Zahoor Sarwar for being there for me throughout the entire MS program. You have been my best inspiration in difficult time.

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List of Abbreviation

TPS	Toyota Production System
WIP	Work-in-Process
SMEs.	Small Medium Industries
GDP	Gross Domestic Product
JIT	Just-in-Time
OEP	Overall Equipment Performance
OEE	Overall Equipment Effectiveness
L.P	Long parts
EDM	Electric Discharge Machine
QA	Quality Assurance
PLC	Programable logic Control
QAD	Quality Assurance Department
PTO	Power Take off
FGD	Focus Group Discussion

Chapter 1

Introduction

After the Second World War, the Toyota Production System begins to initiate the concept of the Lean Manufacturing System. “At that time the Japanese industry had very low productivity and a huge lack of resources, which prevented adopting the model of mass production” [1]. Two engineers (Kiichiro Toyoda and Taiichi Ohno) visit a car plant FORD US to understand the process. After visiting, the idea of the production process was developed and implemented in Japan and that idea is now known as Toyota Production System (TPS) [2]. The automotive industry has become the centre of attention in the manufacturing sector of the world. Productivity is the critical success factor for every organization in the competitive environment. The industries are facing different challenges with integration and reorganizing [3]. In the context of implementation, the different barriers exist in different levels of the organization like managerial, technological, and cultural. The absence of knowledge of lean manufacturing and modern technologies are the barriers in the implementation of lean [4]. Lean manufacturing system discussed two concepts only which are Just in time JIT and autonomation concept these are the pillars of Toyota Production System. In the Just in time (JIT) concept, producing the product when it is needed and in the autonomation concept, automation with the help of human factor.

Positive Lean manufacturing system explained with three Japanese words are Muda, Mora and Mori. Japanese word Muda means the elimination of seven types of waste from the manufacturing system which are overproduction, unnecessary transportation, waiting, extra processing, motion, inventory and defects. Mora means the elimination and identifies the waste from the execution of lean and coordination waste of human resources. The Japanese word Mori has double meanings. First is overburden which means that highly utilized the resource. The second is stress which means that the emotional aspect of work. Increase the understanding of tasks, which makes it possible to perform easily. Standardized work is the pillar of the lean manufacturing system therefore everyone repeats the same best procedure for work [5]. Improvement of organizational performance with the consistent betterment of management philosophy can help to meet the customer demands with minimum cost and high quality [6]. In today’s dynamic business environment of the world, every industry persists in the

competitive market through providing soaring customer service, low-cost products, and miniature lead time. Therefore, the industries are more customer-focused and putting effort to minimize the lead time, cycle time, delivery time and improve quality to achieve more customer satisfaction [7]. In the future, lean manufacturing systems and tools will become most important in the manufacturing sector and increase the competitive environment for manufacturers. Elimination of waste from the production process applied lean tools and techniques to achieve good quality products, decrease delivery time and cost-efficient are the main target of the managers. The lean manufacturing system is simpler, adaptable, ergonomic, compendious, profitable and it requires less energy for implementation [8]. The lean manufacturing system is called the waste reduction technique and it is maximizing the value of products. This technique is used to identify the value-added activities and non-value-added activities. Defects, over-processing, overproduction, excess motion, waiting, redundant transportation and futile inventory are the different sources of non-value-added activities, which can be a hurdle for value-added activities [9]. Therefore, increased manufacturing defects are making us realize the importance of lean manufacturing. Anything which cannot add some value to the finished product is called waste. The lean manufacturing process is like a socio-technical system because the lean manufacturing process covers the cultural and technical prospects. According to different studies, the most important factor in a lean manufacturing system is material handling because material handling cost is estimated at 17% to 70% of the total operating expense, the material cost increases due to poor layout [10]. Human factors and lean implementation should be considered at a parallel level. Improvement execution is done with the help of concerned people in a professional work environment. Some industries implemented the lean concept, but they couldn't achieve the desired result. Because during the implementation of lean, the top, middle and lower-level management did not adopt as a culture [11].

The material flow will be smooth according to the lean concept and free from problems. Organizational success is measured according to a three-point view, i.e. social, cultural and operational, which could impact organizational performance [12]. The human factor is the main component of lean manufacturing, the knowledge of workers and management staff affects the success rate of its implementation. Cross-training of the employees encourages knowledge transfer and improves the business process [13]. Pakistan Automotive industries used just the production improvement methods, but not

adopting the concept of a lean manufacturing system as a culture. Because the industries only focus on lean manufacturing system and tools, not on the human factor, which makes the lean manufacturing system ineffective. The international manufacturing trend is changing day by day due to customers' demands. Survival in a competitive environment and understanding of the implementation of lean techniques and tools should provide the training to senior staff and management [14]. The impoverished mentality and unequal understanding cause the failure of implementation of the concept of lean manufacturing. The human factor is the main component of the lean manufacturing system. Therefore, social and technical aspects should move in parallel, thus reducing the waste in the manufacturing process, making the process more efficient and create a more suitable culture in the organization. If these organizations ignore the human factor, then they will face difficulties to maintain their position in the competitive environment [15].

1.1 Knowledge Gap

The knowledge gap regarding the implementation of positive lean manufacturing in the one of the manufacturing units of automotive industry of Pakistan has been researched. The human factor has become the most important in the implementation of lean. Most of the researchers had focused on the technical aspects during the implementation of lean and ignored the human factor. This knowledge gap is constructed from a literature review of different research papers. This research helped to find the effects of implementing positive lean manufacturing on the production and quality of the products
Problem statement or research questions
Problem statement.

1.2 Purpose of the Study

The purpose of this study is the implement Positive Lean Manufacturing in one of the manufacturing units of auto sector of Pakistan and evaluate its results. During implementation eliminating waste, improving processes and increasing the skills of the employees and importance of human factor in manufacturing will my focus, which will help to increase production, produce good quality and low-cost products.

1.3 Motivation

The research that has been carried out in implementing positive lean manufacturing is not adequate for production procedures and productivity improvement. Pakistan's automotive sector has great potential for productivity improvement. Because the automotive sector could play an important role to increase the country's GDP.

1.4 Significance of the Study

This research can be focused on the implementation of Positive Lean Manufacturing in one of the manufacturing units of automotive industry of Pakistan. Intensive research work has been done in the field of implementation of Positive Lean Manufacturing in the world, but the Pakistan Automotive industry is not getting fruitful results from that research. Most of the industries are following the traditional manufacturing methodology to resist change. Industries, which realized the importance of lean manufacturing have moved towards lean manufacturing. But due to a lack of necessary lean knowledge and importance of human factor, they are unable to produce the expected result (i.e., wastage removal, enhanced quality, efficiency, productivity, and customer satisfaction) because they ignore the human factors and want to implement lean manufacturing without involvement employees. Despite Intensive research, researchers have not been able to find much data on implementing Positive Lean Manufacturing in the Pakistan Automotive Industry.

1.5 Problem Statement

Ignoring human factor in the implementation of lean manufacturing have resulted in low productivity level and success rate in Pakistan automotive industry.

1.6 Research Questions

Q1: What are the flaws in Existing manufacturing system?

Q2: How to implement Positive Lean Manufacturing system in the existing manufacturing setup using human factor?

Q3: Identify the importance of human factor in pre-decision process and wastages in the Production Process of the Automotive Industry?

Q4: What is the impact of the Positive lean manufacturing system in the Automotive Industry?

1.7 Research Objectives

- To study the flaws in Existing manufacturing setup.
- To examine the implementation of a Positive Lean Manufacturing system in existing manufacturing system focusing on the human factor.
- To determine the importance of human factor in pre-decision process and wastages in the production process of the automotive industry.
- To study the impact of the Positive Lean Manufacturing system in the automotive industry.

Chapter 2

Literature Review

The current competitive economic environment for industries to survive in the global market with the production of high-quality products and minimum cost. Pakistan's automotive industry lacks an understanding of the implementation of the Positive Lean Manufacturing concept [16]. The lean manufacturing system is not new, it already has been applied in industries for many years. Most of the industries have acquired a low success rate of lean implementation system due to failure in the management of changing process. The lean manufacturing process includes the changing and improving process. Therefore, the challenge will be faced in the transformation of many aspects and stages, but implementation gives long-term benefits [17]. The industries are facing challenges due to global competition. People and the workforce play an important role in the implementation of lean. The Proper implementation of lean will increase job opportunities. If the number of workers increased in an organization, the possibility of problem-solving with a variety of tasks will be increased. The use of the human element is useful in the transformation process towards lean manufacturing [18]. The success of lean implementation does not depend only on the technical aspects, but also the consideration of behaviour and action of employees and management is needed [19]. Implementation of positive lean can bring benefits, but the implementation process will be different in different organizations. The implementation in a large organization will be different according to small and medium industries. If an organization fails to implement the lean and then this failure impacts the organization's resources but also affects employee’s confidence and behaviours [20].

A lean manufacturing system is a powerful tool that highlighted the difference in processes and identifies the areas of improvement [21]. If human resource is used as a lean tool in an organization that could promote rapid improvements in the organization. The more reliable result is achieved from the awareness increased of employees in quality, production process and management objective. Training of these purposes done which can be more helpful to achieving the success of lean tool implementation [22]. Cost is required to implement the lean. Educating the workforce was result in increased efficiency of the organization and the work done by the workers more diligently [23]. One of the barriers in the way of implementing lean manufacturing is not to utilize the talent of the workforce. Continuous improvement depends on engaging, developing and

master people to solve the problems in the organization at all levels [24]. This strategy focuses on bringing down non-value activities and increase the efficiency of the manufacturing process. Every industry acquires the market share to maintain a competitive advantage through high-quality products with minimum rejections and gain the identity in the international markets through meet the international standards. Lean manufacturing strategy only focuses on value-added activities of the process. When lean manufacturing strategy is combined with the work-study method, we can find the solution to any problem in any industry. Solving these issues, the occurrence of lean strategy and employee training increase the probability of lean systems success. The industrialist is thinking that the implementation of lean strategy in two stages. First that the partial way to implement the lean strategy. Second is to achieve the lean manufacturing objectives [25]. Lean manufacturing methodology is one of the world's best techniques to improve the efficiency of small and medium enterprises. But during the implementation of the concept face problems. Because SME's are a sign of economic growth and healthy competition in the country. Increase the operational efficiency of the organizations is concerning with the quality, cost and delivery of SMEs. Having the capability of large manufacturing enterprises to implementation of lean concepts due to many resources. But in other side having less capability of implementation of lean concepts due to lack of resources. Roger Hall, chief executive officer of Tennant Company explains the situation in a better way than "we found that, like another important idea of quality is elementary. As simple as it is difficult to understand." This statement explains the same situation as the concept of lean manufacturing with different tools and rules. Lean concepts are associated with two different practices. One is soft practices and second is hard practices. Soft practices are related to peoples and their relations. Hard practices are related to lean concepts techniques and analytical tools. According to the lean concept, the total cost reduces when reduced the unit cost of the production. Face the market challenges, situations and eliminate the waste of the organization through implementation lean manufacturing concept. When mistakes happen in organizations, for example not defining the standard of execute of lean concepts, the stride of work not enough in organization and scantiness of audibly defined vulnerabilities that to imprecise the distinguishing the requirements of internal and external customers [26].

The purpose of the lean implementation is to reduce wastes and increase the efficiency of the business process, but the involved people satisfaction is achieved. The

environment of the organization should be people-oriented, through promoting the development of the workforce training and involvement in decision making [27]. The lean manufacturing implementation is facing different challenges, these are cost reduction, the inconsistency of market, competitiveness, and continuously changing demands. The current industry 4.0 initiatives minimized the obstacles concerning human resources, customers, suppliers, and wastes and improve these processes. The proper way of application of lean tools and techniques through industry 4.0 initiatives, the industries make possible to reduce the risk of non-value-added activities [28]. Industry 4.0 is the fourth industrial revolution. This revolution integration of humans in the manufacturing process, continuous improvement and concentrate on value-added activities with the elimination of waste. this revolution enables flexibility in manufacturing systems with the help of a smart machine and smart product involving computer integration [29]. The lean manufacturing system is used to identify the waste but must identify the waste and strategy relationship. Which strategy is more efficient for one type of waste? Which finds the best available solution in an organization related to this kind of waste [30]. The main goal of lean manufacturing is to control the inventory and quality of products with minimum cost and disbursement of resources. These actions have been taken to create value for customers. The different levels of concept in lean manufacturing are defined as a philosophy, set of essentials and a bunch of exercises. When lean manufacturing is implementing then some principles keep in mind. Identify customers and their value, identify the sequence of the process of production, establish the sequence of the extinguishing of waste, design the process of delivering services according to the customer and maintain their consistency towards improvement [31]. In the small and medium industries, how is to implement lean techniques and tools. The knowledge of overall equipment effectiveness (OEE) is the main factor of lean implementation in SME's and has segregated the improvement steps and control the operations.

The strategy of continuous improvements through the elimination of wastage of resources is called lean manufacturing. Producing high-quality products and services through the implementation of a lean manufacturing strategy in the industry for competitive advantage. Different tools of lean manufacturing use in different organizations like Just in Time (JIT), 5S, KANBAN, Poka Yoke and KAIZAN. Improving the quality and productivity of the process and abolishes wastes through lean manufacturing in manufacturing industries. In the 21st century, the manufacture the

high-quality product at the lowest cost with the help of implementation of these types of strategies are the best solution to attain a competitive advantage in the international market.

In the current competitive environment, every industry allocates resources for improving productivity carefully, only focus on the process of production. Utilize the optimum manpower, machine time, lead time and application of different tools and strategies, to identity waste and eliminated it. Implementation of computer integrated manufacturing and computer base lean audit systems in a manufacturing environment are necessary for survival in a competitive global market era. when lean audit systems are implementing in industry, then focus on the study of time, take time and setup time of the manufacturing, because the concept of KIAZAN and computer integrated lean audit system is used to help increase the addition of value-add activities [32]. Two types of tools are implemented in the current manufacturing system, which can help to find the success key factor and process of lean manufacturing. These tools were used as a gap analysis and value stream map, which can minimize the waste in the manufacturing process [33]. With the implementation of lean manufacturing, only 10% of industries achieve the desired result. A lean manufacturing system is described as set-off processes and actions, which can be started with planning, identifying the success factor and information system. This manufacturing technique ensure the efficient use in continuous improvement of product quality, delivery time and customer satisfaction, which can be the establish a positive environment [34]. Most organizations take the advantage through implementation of lean manufacturing which help to increases quality and production. But other factors like the size and age of organizations affect the result of a lean manufacturing implementation. When lean manufacturing techniques have to be implemented, then the different types of waste should reduce from the organization (i.e. waste of overproduction, waiting, unnecessary motion, transportation, over-processing and inventory) [30]. The organizations are achieved their aim and objective with the implementation of proper planning, Just-in-time (JIT), and application automation in the production process. Implementation of lean techniques in organizations achieves the different benefits (i.e. minimize the operating cost, quality control, increase in sales, reduction in lead time, and continuous improvement) [35]. When a lean manufacturing system is implemented in the manufacturing system then focus on the overall equipment process (OEP). Every manufacturing system is involved in different tools, if utilizing the maximum efficiency

of tools then would achieve the maximum productivity and quality [36]. The customer's requirements changing time to time therefore the difficulties are faced to implement the management philosophies and strategies. Identify the customer's needs with perfection and eliminate the waste through uninterrupted continuous improvement with zero defects. Implementation of lean manufacturing in the industry of Gaza Strip has minimized 57% steps in the whole project, 81% to 14% reduction in non-value-added activities and the cycle time was minimized 75%. Managers are only focused on some lean tools and continuous improvements but forget another important principle of lean that is "respect for people"[37]. when a manufacturing execution system implemented through lean manufacturing, they will be identified theory and the practical gap between theories and philosophies of lean manufacturing [38]. When lean implement in organizations then the industries have not a monitoring system of implementation which can reduce the success rate of implementation. the real-time monitoring system introduced in lean implementation to identify the gaps and factors influencing the success rate [39]. Implementation of lean manufacturing technique has limited attention on the human factor. But the human factor supports the adoption of lean. The different actions perform to helpful for the adoption of lean like human resource management, labour coordination and organization constructive learning involvement [40]. Different factors affect the success of the implementation of lean, like that are management, employee training and involvement of employees in improvement procedures [41].

2.1 Conceptual Framework

Pakistan automotive industry is the major component of country economy. In this study focused on different parameters which can be helpful to find the effects of implementation of Positive lean manufacturing. First step of this research to select the Assembly line of Fire fighting vehicle, Water Bowzer and Manufacturing Section of the Government Organization which are supply these vehicles and different parts of vehicle to other Government organization according to the demand. After selection of this organization checking the documentation of the assembly line of Fire Fighting Vehicle, Water Bowzer and Manufacturing Section. This organization have the status of “supplier” in whole country for other government organization. Documentation is playing the main role in the success of the organization. Because the documentation is used to track and trace the flaws in achieving success. The next process was to observe the production process and write down the flaws and improvements which can be

improved in the production process with help. After writing the flaws, calculate the processing time on every stage and note the non-machining time in the process.

Wrote the points which can be noted from the observation of documentation, production process and Time & Motion study and improvements suggestion. These improvements were discussed with workers and management that how to improve the process, decrease the fatigue of workers, how to motivate the workers through reward and appreciation culture and discuss the steps or process of manufacturing to take

Figure 1: Conceptual Framework

ownership of these improvements. or any other suggestions from the worker and management side and should be included in the list of improvements. After the discussion with workers and management implement these improvements which have been finalized in a discussion. Collect the data after these improvements have been implemented and calculate them effects. Write the analysis report after implementation of these suggestions before and after implementation. In the last conclude the result before and after implementation.

Chapter 3

Research Methodology

This research aims to describe and explain the impacts of the implementation of Positive Lean Manufacturing in one of the manufacturing units of government organizations in the auto sector of Pakistan. The research is descriptive, explanatory, applied and a quantitative and experimental research technique was used. A quasi-experiment was used to gather information. A Positive Lean Manufacturing system is proposed included in this investigation.

3.1 Research Design

Unluckily, the issues in the manufacturing process of the automotive industry of Pakistan still exist. The fear of management, lack of resources, less utilization of manpower and lack of knowledge of implementation of the positive lean manufacturing system are the main issues highlighted in the automotive industry of Pakistan. With this lack of attention, the Pakistan automotive industry did not sustain its position in a globally competitive environment. The solution to this problem is to identify all the wastage of resources, gaps in the manufacturing process, utilize the manpower of the organization and increase the skills, motivate the workers, describe the job responsibilities and duties, standardize the work through an improved process flow chart, provide the detail and assembly drawing to the workers, quality checks, daily production record. The Pakistan automobile industry, ensure the proper implementation of a positive lean manufacturing system and create the exposure of positive lean manufacturing concept in employees. The productivity will increase after the involvement of the human factor like the motivation of the worker, job description, standardized work and involvement in the pre-decision process in previous manufacturing setup can help to increase the production of high-quality products by minimizing the cost. Motivate the workers or employees through a reward and appreciation culture in an organization. Explained the general task and related duties and responsibilities for every person at every stage of the production line. The whole work makes standardized for workers to perform again and again according to the job description and involvement of workers in the pre-decision process to help the efficient implementation of positive lean manufacturing.

Quantitative research is utilized to measure the issues by creating numerical information or information that can be changed into usable statistics. So, quantitative research was conducted using a quasi-experiment method to achieve. This research aims to depict and clarify the effects of implementing positive lean manufacturing in the automotive industries of Pakistan.

3.2 Sample Size & Sampling Technique

The data was collected from the targeted government manufacturing unit of the auto sector of Pakistan. Information was collected from the different stages of the assembly line and different sub-sections of the manufacturing section with the help of assembly line and manufacturing section workers, Sub-Section supervisor and production manager.

3.3 Data Collection

Data collection is one of the main components of the research to perform analysis. The data was collected from the targeted manufacturing unit, where positive lean implementation was done. Information was collected from all the production processes in different sub-sections of the manufacturing section and stages of the assembly lines for evaluating the organization's production and manpower skills. Used three different ways for data collection, firstly conducted short interviews from assembly line workers, sub-section heads and supervisors about the manufacturing process, machines layouts and flow of the process. When short interviews were conducted with the supervisors about the manufacturing process, quality control, machines layouts, material and manpower, the basic theme construed from interviews was converted the numerical form. Second, observed the assembly line stages and different sections of manufacturing section 2. The third was focused group discussion (FGD) in this way gathered the specific operation or product-related workers, sub-sections heads and supervisors to discuss that how to be improved the specific process and production. Information about processes and timelines was gathered. Important points were noted that worker's skills level, how many machines, equipment and manpower are used in the manufacturing process. Also, the data was collected from the layout of the assembly line, process sequence and inventory control system with the involvement of workers, supervisors, and managers and asked about how to improve. Merge all the data was to be done, which was collected from short interviews, observations and group discussion.

Write down the implementation sequences with the improvement of layout, machines, equipment and human resource management with motivation of workers through reward and appreciation culture and Job description on every stage for every worker for every operation. Standardized the work through process flow chart, detail and assembly drawings, standard quality checks and daily production record and involvement of workers, supervisors, section heads and management of the organization to design the improvements and implementation sequences. The discussion was made with the assembly line and sub-sections supervisors, and managers to finalize the changes in the proposed implementation sequence and any change in the layout of the machines, process, inventory control system and utilization of assembly line workers.

The data was arranged after discussing the finalized changes in the implementation sequence. Implements the finalized improvements in machines layouts, manufacturing process. For analysing the effects of the implementation of positive lean manufacturing the data was collected again from the assembly line and daily production report in the manufacturing section. Discussed with the workers about to ensure the improvements successfully implemented like the quality procedure, layouts of machines, allocation of material and tools and process of manufacturing. when the discussion is made with workers then find the answer to these questions that how much time is required to finalize the product, how much time can be reduced in different stages of the assembly line and how efficiently use the manpower on the assembly line. How much time reduce in the product manufacturing after dividing the manufacturing section into sub-section and the addition of special-purpose machines for the specific required products.

3.4 Data Analysis

The Matrix Laboratory (MATLAB) has been used for data analysis because of its versatile nature and analysis feature. It is nearly to become necessary for professionals [42]. All the gathered data was entered in MATLAB in the form of coding. The data was converted into the “plotting cool graph” as result, these graphs show the effects of the implementation of improvements in the manufacturing process. MATLAB is the computer language that is used for multipurpose. MATLAB is also used to visualize and explore the data through customized graphic objects and develop different types of charts with different types of annotating and formatting.

Quasi-experiment is like experimental research. The data was gathered based on some questions with the help Quasi-experimental method. The data was collected from the workers, supervisors and managers of the assembly line and different sub-sections of the manufacturing section for getting the answer to research questions. when the data was collected, it was in different forms like numerical, short interviews about the manufacturing process, quality check process, training and layouts. The basic theme was constructed from the interview through thematic analysis that identifies the flaws in the manufacturing process, machines layouts, manpower and material handling. These flaws can be eliminated according to the worker's suggestion that the fabrication section is separated from the assembly line and shifted end of the manufacturing shop. The work has can be divided into different stages of the assembly lines which could be performed on the different bays and the manufacturing shop 2 can be divided into different sub-section according to work. The data was converted into a complete numerical form to enter in MATLAB and then generate the plotting cool graphs for time and motion study analysis. These graphs can be shown that the effects of the implementation of positive lean manufacturing and how much time were reduced, how much manpower was utilized efficiently.

Chapter 4

Results and Findings

4.1 Previous Layout of Manufacturing Shop 1:

There were number of issues identified in the current Manufacturing shop 1 layout. In the current layout, there was only one entrance and one route for both projects. The assembly line of Fire Fighting Vehicle and Water Bowzer was to the right of the Group and this single assembly line was used for all the projects, thus creating an inefficient layout with different requirements. The metal store was not located in the best possible location which could facilitate the flow of raw materials. The machine section (lathe, milling and grinding section) was located to the left of the group. This section was very small, so most of the fabrication and final assembly work was done on the assembly line, resulting in slow production.

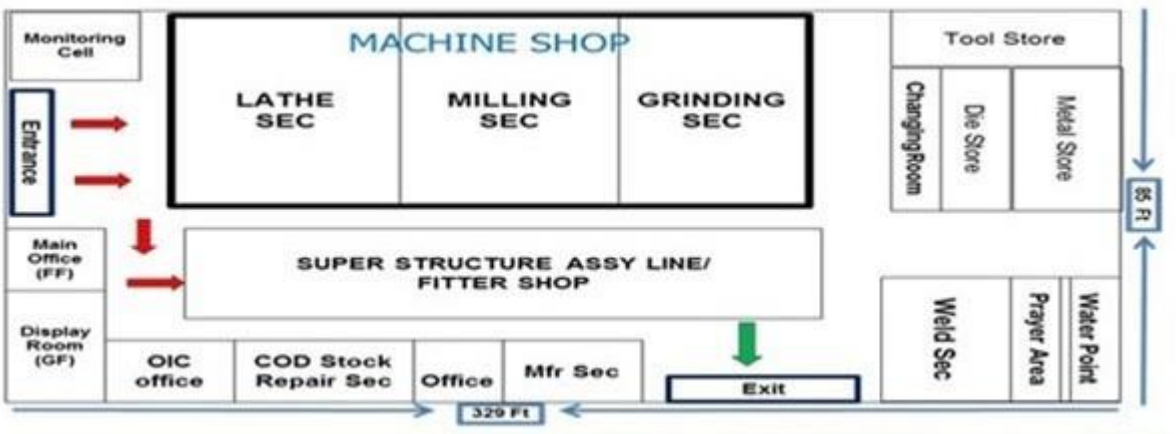


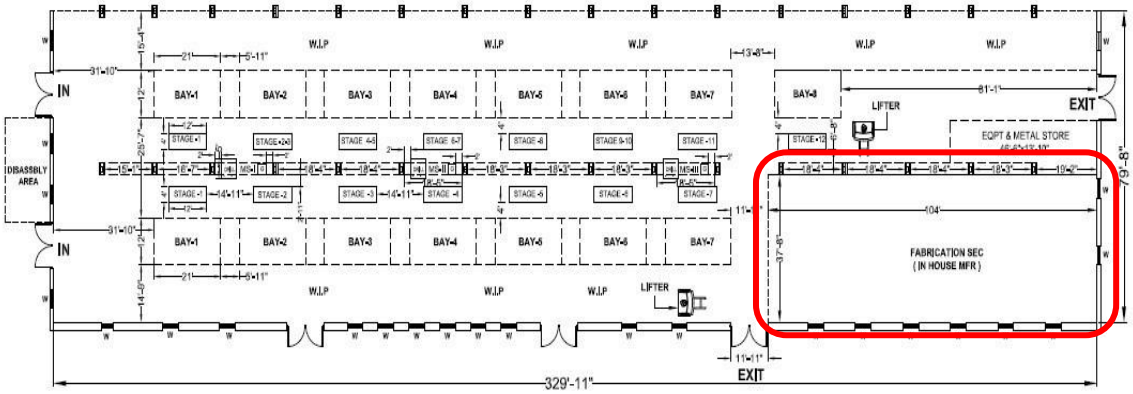
Figure 2 : Previous Layout of Manufacturing Shop 1

The flow of the machining section was also not explained. Some operations, such as sharing, notching, and banding, were carried out in an outsourced group, resulting in longer waits, longer travel distances, and ultimately slower production. Another problem with the current configuration was the indefinite process flow, an operation continuity of assembling different parts, received from different groups or even outsourced vendors. Work is not defined thus responsibility for work, quality and timely availability of workers wasn't clear.

4.2 Designed layout of Manufacturing Shop 1:

One entrance gate for each project of fire fighting vehicle and water bowzer assembly lines were designed separately in the designed layout. Disassembly area was shifted

outside the Manufacturing Shop 1. Work of stage zero was performed on the disassembly area where the unnecessary parts were removed from the vehicle for further modification. The fire fighting vehicle assembly line was divided into 8 Bays and 15 working stages. Assembly line of water bowzer was divided into 9 stages which completed on 7 bays. Separate exit gates are designed for both projects, the L.P store was separated from the tool store. The machining section and fabrication section was designed separately from the assembly lines. The metal store was shifted near to the Machine and fabrication section. Three small machine stations were shifted between the two assembly lines to support the assembly lines. The concept of work in process (WIP) was designed and the area for work in process was allocated beside the assembly

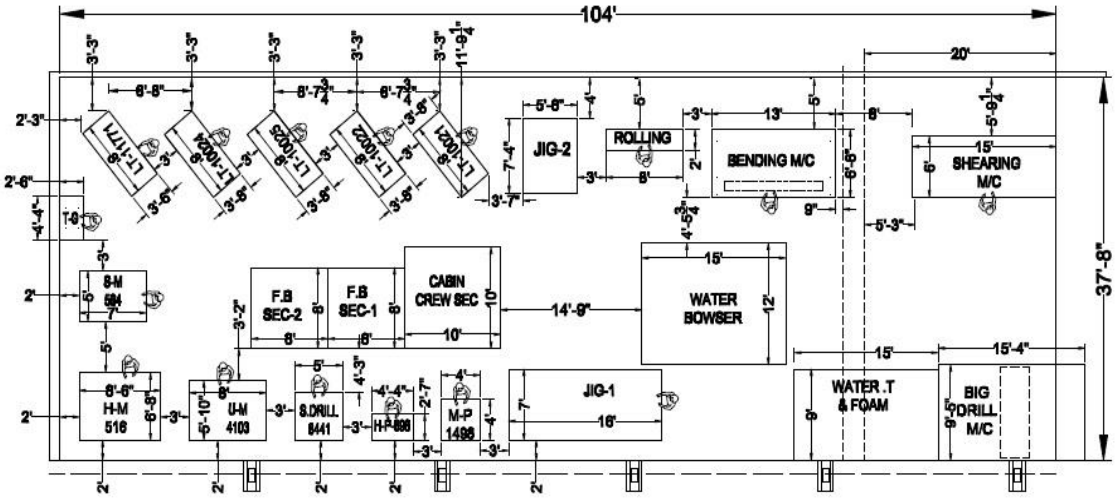


lines. Enough space was provided in the designed layout for lifter movement.

Figure 3: Designed Layout of Manufacturing Shop 1

The highlighted area in the above figure 4 is the Fabrication section which is shown in detail and clearly in figure 5. In the Designed layout the numbers of machines reduced from thirty-one to twenty-nine. The sections of small machines were shifted from side walls to the centre of the assembly lines. In the designed layout the machines were installed according to the workflow. Machines used in Machining & Fabrication section were according to the workflow process like Sharing Machine is used for sharing the metal sheet according to the fabrication drawing for water tank, foam tank and other required work. Bending Machine is used to bend the metal sheets according to the fabrication drawing. Roller Machine is used to roll the metal sheets according to the drawing and Lathe Machines are used for threading of piping/ coupling, Brass nozzle of sprinkle, railing brackets of fire fighting vehicle and water bowzer Foam inductor. Tool Grinder is used to grind of milling and lath tools and Horizontal & Universal Milling Machine is used to Fabrication of foam inductor and Drill of flange through

dividing head. Slotter machine is used to cut keyways on the shaft. Removing and fitting of bearings & bushes with the help of Hydraulic Manual Press. Manual Press is used to the straightness of channel's & shafts. The Big Drill Machine is used for holes which were not possible on small four spindle drill machines. Small Drill machine is used to drill the holes in normal thickness of sheet but can't be used to drill for dia and



thicker sheet. Jigs are used to maintain the required measurement and shape of the sheet.

Figure 4: Designed Layout of Fabrication Section of Manufacturing Shop 1

Small machines sections consisting of nine machines, which are used for both assembly lines. Every machine section contains two machines (Four spindle drill Machine, Bench Grinder and Welding Plant).

4.3 Previous Layout of Manufacturing Shop 2:

There were many issues that were identified in the Previous layout of the Manufacturing Shop 2. Some of the major issues are considered here. In the previous layout, there was two entrance & four exist for all projects. Two out of four exist gates used for scrap storage which was throw in open area. Previous layout was very complicated. Generally, four bays divided into different shops. But due to mismanagement and poor layout designing many spaces were empty and other spaces were overcrowded with machines and workers. On the first entrance CNC lathe machines was installed in a separate room. Bay 1 was total empty and few machines, which were not in use for daily projects and works, were installed. Main machine shop was in bay 2. Lathes machines which were centre lathe, capstan lathe, simple lathe machines and some surface grinders and small tool grinders were installed.

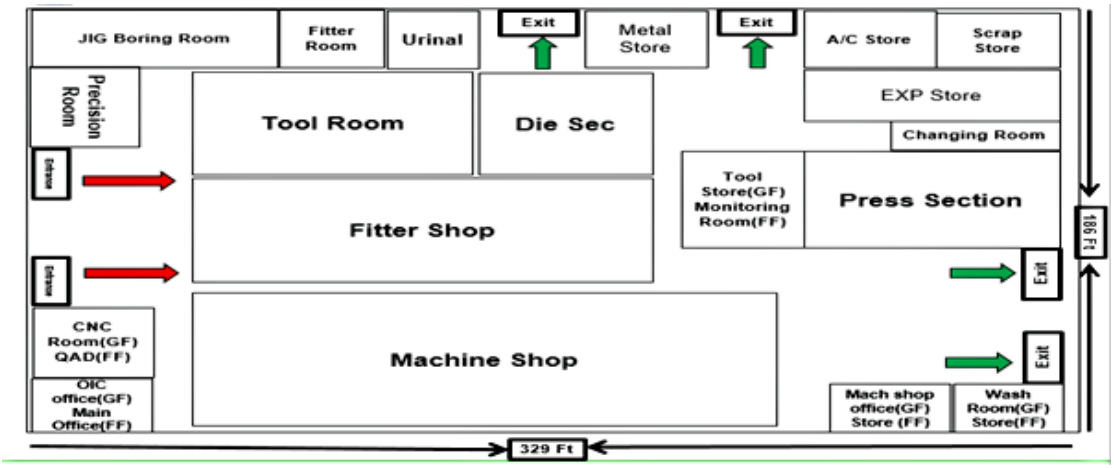


Figure 5: Previous Layout of Manufacturing Shop 2

For milling machines were installed into separate section which was named milling section. Separation between machine section and milling section reduce production due to time consumption of distance between machines. Bay 3 was named fitter section, which was used for fitments of parts and gauges. There were few machines like shearing machines, bending machines, welding plants etc. installed in fitter section. Bricks construction between fitter section and press section also declined rate of production. Tool store and monitoring room build in bay which directly impacted the workflow. Press section was located at the end of bay 3. Press section was also isolated with bricks boundary wall and given small entrance. With these complicated and improper layouts, machines installation was creating big problem for movement of parts and materials throughout the group. On the entrance of bay 4 precision grinding manufacturing room was located. In the room 5 precise grinding machines was installed for production of gauges. In bay 4 tools manufacturing section was located which included milling machines, grinding machines, lathes machines, special purpose milling machines, special purpose grinding machines and large drill machines which were used for production of different tool. After that tools manufacturing section die fitter section was located. Which helps in tool manufacturing. At the end of bay 4 other solid constructions like changing room, EXP store etc. was build. Which also occupied much space in that bay and created hurdles in workflow. There were some side rooms which are jig boring section, gauge fitter and store. In the previous layout, proper spaces are not identified between sections which resulted in creating hurdle for material handling and lifter movement.

4.4 Designed layout of Manufacturing Shop 2:

In the Designed layout there were two entrance gates for all types of projects of manufacturing section. Four exist gates were proposed in new layout which helped control and improve movement of materials and parts. Visitor gallery was built inside the group before all manufacturing sections. 3D printing technology was first time introduced in Government organization in Pakistan automotive sector. 3D printing room has also been built inside the group to support the group manufacturing requirements.4 bays were divided into different manufacturing sections by their working and production of parts. Proper path was allocated for material movement and lifter movement. Path will connect all manufacturing section with each other. Main manufacturing section was further divided into 18 small sections which support their manufacturing department. These sections are cell section, die fitter section, CNC die manufacturing, general manufacturing section which can be divided into 15 cells, specialized manufacturing section, press section, precision manufacturing section, packing section, fitter section, jig boring section, and precision grinding section. Furthermore LAB, QA section,3d printing room, conference room, staff room, and ANCY room were also build into the manufacturing section. Total of 161 machines were installed into the manufacturing section to deal with different projects. But there is also a deficiency of 13 machines which has purchased from the market to support the group. After purchasing these machines, the group working with full capacity.161 machines include lathe machines, milling machines, grinding machines, drill machines, slotter machines, planner machines, shaper machines, press machines, auto screw

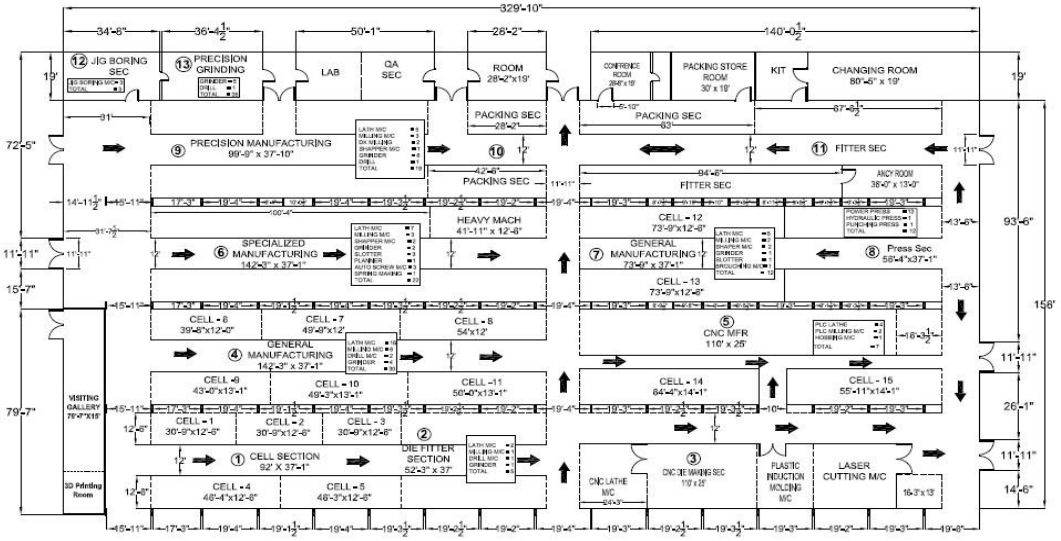


Figure 6: Designed Layout of Manufacturing Shop 2

cutter, shearing machine, bending machines, jig boring, CNC lathe and milling machines, PLC lathes and milling machines, leaser cutter, CNC Wire cut, CNC EDM machine and spring manufacturing. By the nature of work and requirements these machines will install into their different sections.

4.5 Sub-section of Manufacturing Shop 2:

4.5.1 Cell Section (Cell 1 to 5)

4.5.2 Die Fitter Section

4.5.3 CNC Die Manufacturing

4.5.4 General Manufacturing (Cells 6 to 11)

4.5.5 CNC Manufacturing Section

4.5.6 Specialize Manufacturing Section

4.5.7 General Manufacturing (Cells 12 & 13)

4.5.8 Press Section

4.5.9 Precision Manufacturing Section

4.5.10 Packing Section

4.5.11 Fitter Section

4.5.12 Jig Boring Section

4.5.13 Precision Grinding Section

4.5.14 Lab

4.5.15 QAD Section

4.5.16 3D Printing Room

4.5.17 ANCY Room

4.5.18 Changing Room/Staff Room

4.5.1 Cell Section (Cell 1 to 5):

The cell section is the same as other general manufacturing cell sections. It includes cells 1 to 5. These cells work as small factories. These cells are designed with the involvement of human factor. Machines are installed after the discussion with workers, supervisor and management. Another general manufacturing cell is the combination of three lathes and one milling machine. Cell 1 to cell 5 are consist of three lathes and one milling machine each. These cells work separately from each other. One new drill machine is required for this cell's sections. These cells sections increase productivity and are

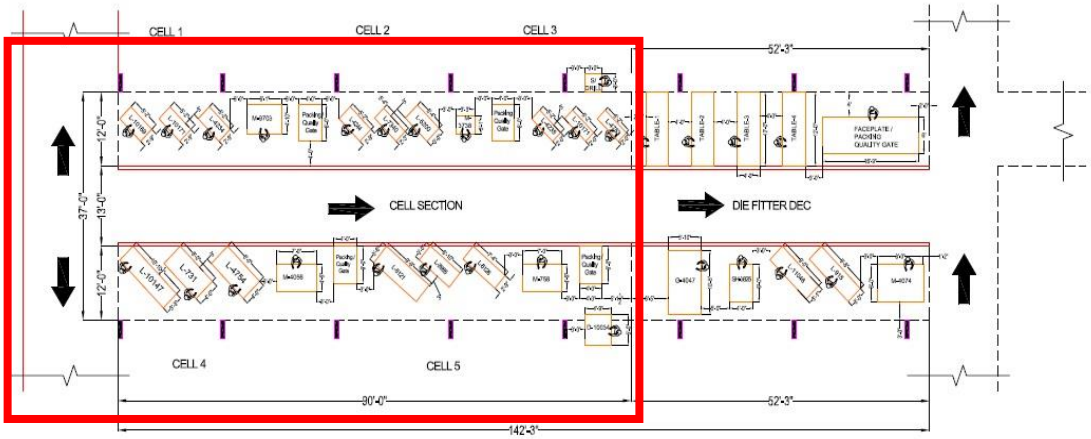


Figure 7: Layout of Cell Section (Cell 1 to 5)

helpful for small productions. Paths for material handling and lifter movement also were allocate in the centre way of these machine. This path connects with the main centre path. Packing and quality gates are also available for these cell sections. With these quality gates, the quality of the finished parts can easily be managed and checked at stage level. And after passing from quality check, parts will be moved to the packing section and get ready to deliver to sponsor groups. In this section 17 person are required to operate these machines.

4.5.2 Die Fitter Section:

Second section of the manufacturing group is Die fitter section. It is supporting section of CNC die manufacturing section. Mainly different die will be manufactured in CNC die manufacturing section and then it's fitting procedure will carry on in die fitting section. Die fitter section designed with the help of workers, supervisor and management. A gate of CNC die manufacturing section connects these two sections. In die fitter section small number of machines provided for fitting purposes. These machines are Lathe

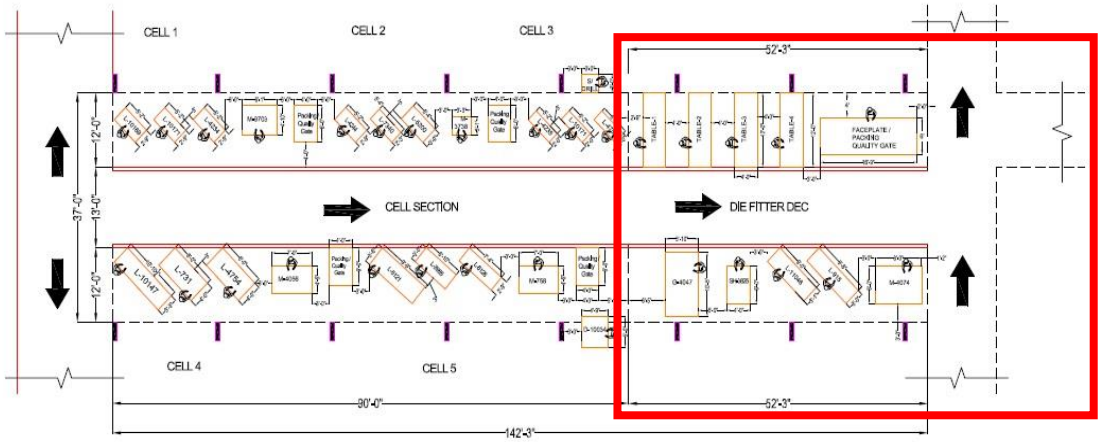


Figure 8: Layout of Die Fitter Section

machines, milling machines, shaper machine, tool grinding machine and drill machine. Furthermore, large size face plate and tables also placed in die fitter section. Die fitter section is in bay 1, very next to the CNC die manufacturing section. In this section 6 person are required to operate machines and other work of this section.

4.5.3 CNC Die Manufacturing Section:

Third section of manufacturing group is CNC die manufacturing. Previously dies were manufactured on manual machines which caused low production rate and low precision quality. Using CNC machines in that section for die manufacturing mainly focus on production increasement and improve quality of dies. CNC die manufacturing section covered with square iron pipe structure and double corrugated sheets which filled with thermopile which provide isolation from heat. The machines of this section were

installed after the discussion with workers and designed the layout of this section. In this CNC die manufacturing section includes CNC lathe, CNC milling, CNC wire-cut,

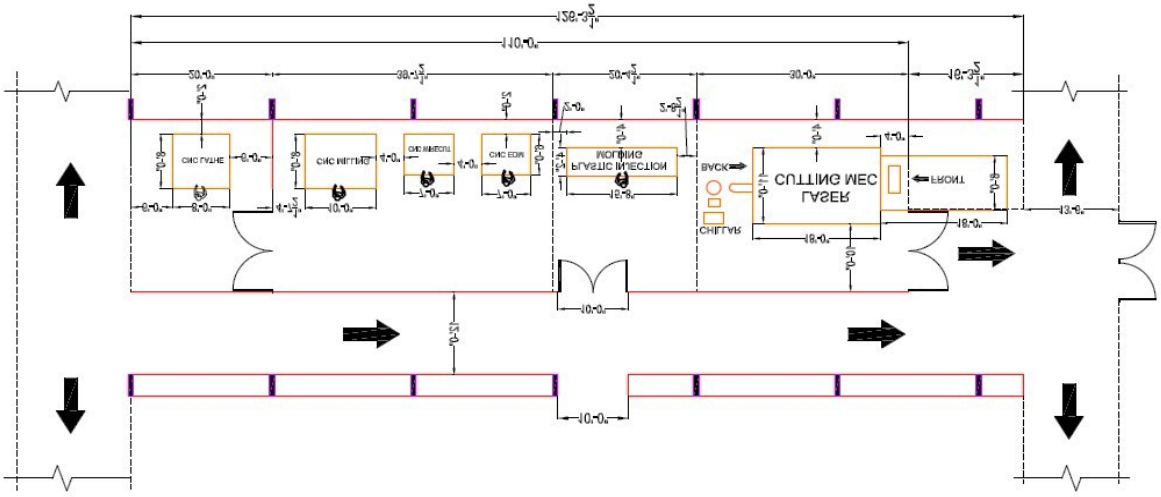


Figure 9: Layout of CNC Die Manufacturing Section

Laser Cutter and CNC EDM machines which are used for productions of different die's which fulfil the requirements of the production groups. Plastic injection moulding plant was also installed in the CNC manufacturing section for production and fulfilling the requirement of plastic parts of this group. Laser cutting machine support the production by cutting sheets in different sizes and shapes. For CNC die manufacturing section which is in bay 1 allocated area was of 88 feet in length and 37 feet in width. 12 feet in width path was managed for lifter movement or material handling management. 3 gates support this section. For this operation of this section, only 6 persons are required.

4.5.4 General Manufacturing Section (Cell 6 to 11):

Section 4 is general manufacturing section of main manufacturing group. It is divided into small cells which work separately from other cells. These small factories work and

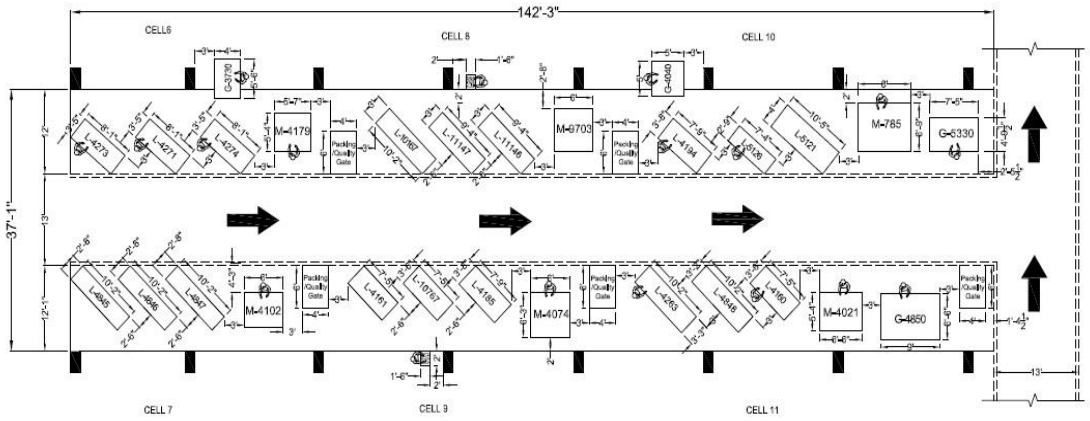


Figure 10: Layout of General manufacturing Section (Cell 6 to 11)

support other groups of the organization. These cells have capacity to produce small and large parts. General manufacturing section is in bay 2 and included 6 cells. Path for lifter movement and material handling was provided in the centre of the general manufacturing section. Every cell has 3 lathe machines and 1 milling machine. Total 31 machines were installed into this general manufacturing cell section. Some tool like grinders were installed to support two cells at same time. Large surface grinders were also installed for large surface work of production. Two new drill machines were required in this section which has been purchased from the market. In general manufacturing section layout design, proper distancing is managed for proper and without hindrance workflow. Four packing quality gates support these six cells of general manufacturing section, which focus on in-house quality of the production and check proper measurements which is required. In this section 23 people are needed to operate these machines.

4.5.5 CNC Manufacturing Section:

In CNC manufacturing section PLC machines are used for special types of projects. Special purpose machines are used for single type of projects in requirements of mass production. In this section the whole machines were arranged after discussion with the workers, supervisors and management for taking ownership for the responsibilities. CNC manufacturing section support large production of manufacturing group. It's also in bay 1 after the die fitter section. Group of four PLC machines include two lathe machines and two milling machines which provide mass production of torsion bars. After these machines two small size PLC lathe machines, which are used for different

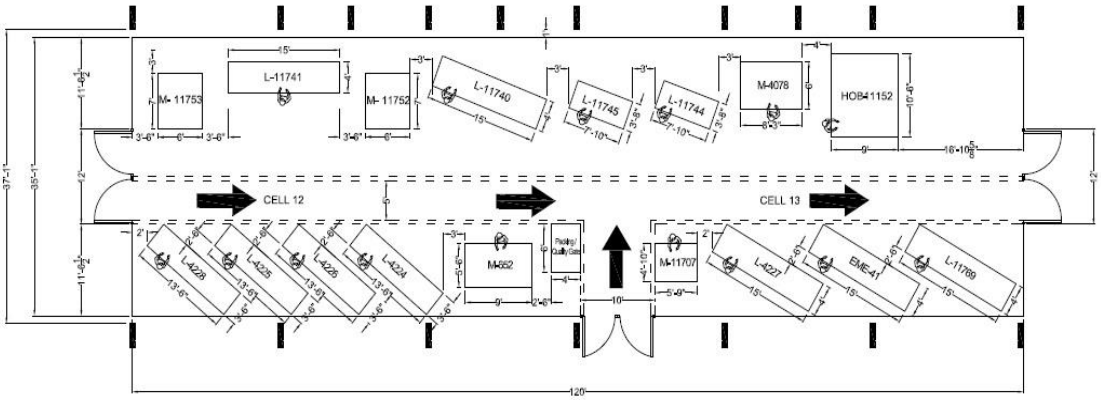


Figure 11: Layout of CNC Manufacturing Section

turning operations for mass production, are installed. Hobbing machine and hob shaper also was also installed in this section, which are used for mass production of different types of gears. Path was also provided for lifter to feed raw material easily. At the end of bay 1, exit gate provide smooth and free process flow and material handling. In this section, 17 persons are needed to operate these machines, including 2 people who can operate four PLC machines.

4.5.6 Specialized manufacturing Section:

In this section of manufacturing group, all special production works are carried out. The specialize manufacturing section is in bay 3. Second entrance gate is linked with bay 3. Special purpose machines were installed in this section. Layout was designed with the help of involvement of human factor because if the workers take ownership of responsibility, then work will be carried out more efficiently. In this section three large special operation milling machines were installed. Capstan and large center lathes machines were also installed in this section. These machines are operated by specialize operators. Large size surface grinders and one planner machines for special operations install in specialize manufacturing section. Shaper machines, slotter machines and tool

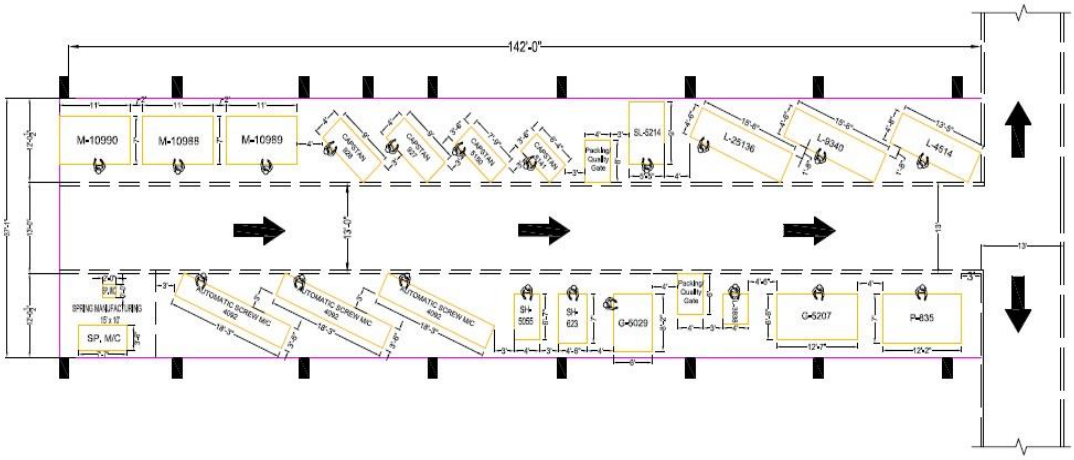


Figure 12: Layout of Specialize Manufacturing Section

grinders install for support of all these machines. Three large automatic screw manufacturing machines also shift in this section and start production of all types of screws. Which is cost effective when start in-house production of screws. A spring manufacturing machine installed in this section. There is vast use of springs in all sponsor groups. Large amount of springs purchased from market which available in high cost. By in-house manufacturing and production of different types of springs production engineering group cut-off purchase cost of these types of parts. In this section, 22 people are required to operate the machines.

4.5.7 General Manufacturing Section (Cell 12 & 13):

The general manufacturing section is the same as other general manufacturing cell sections. It includes cell 12 & 13. These cells work as small factories. But another

general manufacturing cell is the combination of lathes, shaper and slotter machine. These cells work separately from each other. Small surface grinding machines are supporting machines of these cells. These cells sections increase and are helpful for small productions. Paths for material handling and lifter movement also allocate in the centre way of these machine. This path connects with the main centre path. Packing and quality gates are also available for these cell sections. With these quality gates, the quality of the finished parts can easily manage and check at stage level. And after passing from quality check parts will go for the packing section and ready to deliver to sponsor groups. In this section 12 person are required to operate these machines.

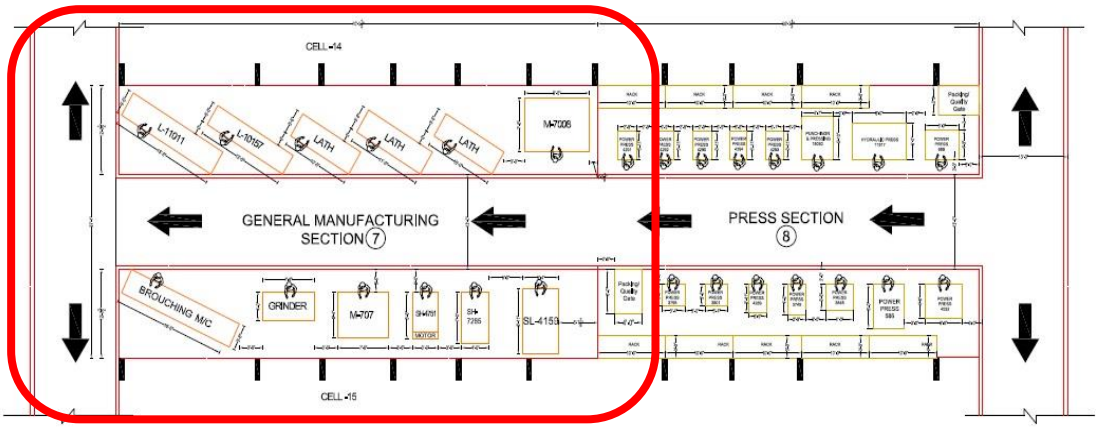


Figure 13: Layout of General Manufacturing section (Cell 12 & 13)

4.5.8 Press Section:

There was lot of work of press into the Manufacturing Shop 2. But in previous layout press section totally separate from the other sections. In previous layout only one and small size entrance provided to press section. Now in designed layout of press section symmetry of machine will be managed. Path between general manufacturing cells 12 & 13 section directly connect with press section. And no boundary wall builds for press section. The dies used for different pattern making. These is arranged and managed in racks. These racks located behind every press machine. For efficient production results

in press section all press machines operated with help of hydraulic power. In those hydraulic press machines seven press machines are small size which has used for general purpose press jobs and holding small size parts pressing. Five hydraulic presses

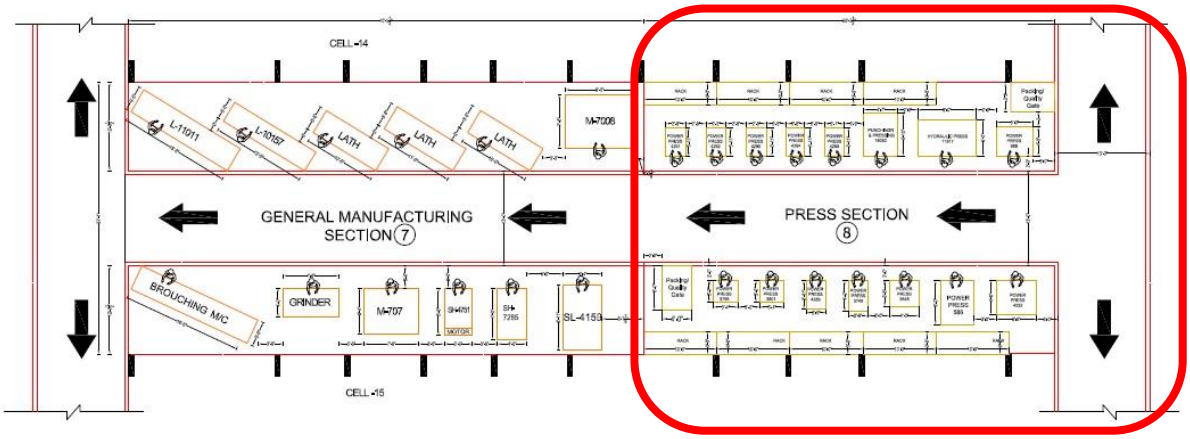


Figure 14: Layout of Press Section

machines are large and heavy-duty press machines. These helps to hold large parts and beams. Overall press section supports all other sections and able to develop all size parts and play efficient role in production of parts. In this section 15 person required to operate all press machines and manage other works.

4.5.9 Precision Manufacturing Section:

Work with full ability and effectively without any wastages and with controlled quality precision parts. The dies of press section have developed in precision manufacturing section. With is allocated in bay 4. This bay has separate entrance and separate exit gate. Path for material handling and lifter movement available in centre of this bay. This path connects entrance gate to exit gate directly. Total 19 machines install in this section. These all machines are highly precise. Small parts and large parts which highly required precision in their measurements and size has deal and manufacture in this section. 5 out of 19 machines are lathe machines which is small. These lathe machines use for turning and tapering purpose. Tool grinders installed near to these lathe machines. Heavy duty surface grinders used for large surface grinding purpose. One heavy duty drill machine installed for large size boring jobs and production. This heavy-duty drill machine also supports all other sections. Five medium size milling machines installed in this section which provide all types of milling operations. One slotter and one shaper machine also installed in this section. Two large size tool grinders installed to grinding the tools which use as a heavy duty machines. In this section 18 person

required to operate these machines and other work of this section.

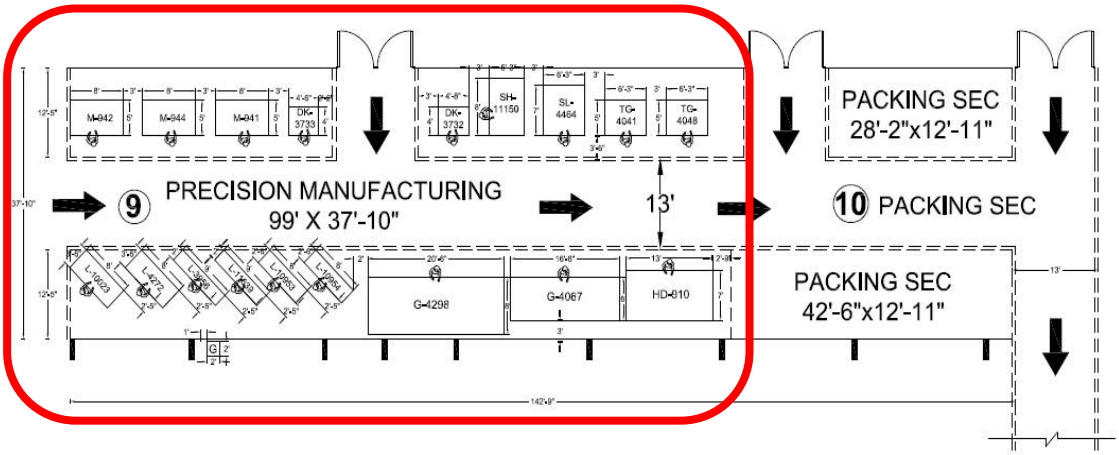


Figure 15: Layout of Precision Manufacturing Section

4.5.10 Packing Section:

After final inspection and passing from quality control and assurance department the parts collect from all sections and ready for packing in packing section. In bay 4 packing section allocate after precision manufacturing section. Same path cross through packing section. All parts pack in this section and then deliver to their sponsor groups respectively. Packing section on both side of the centre path in bay 4. Packing section layout designed with help of workers, supervisors and management. Tables

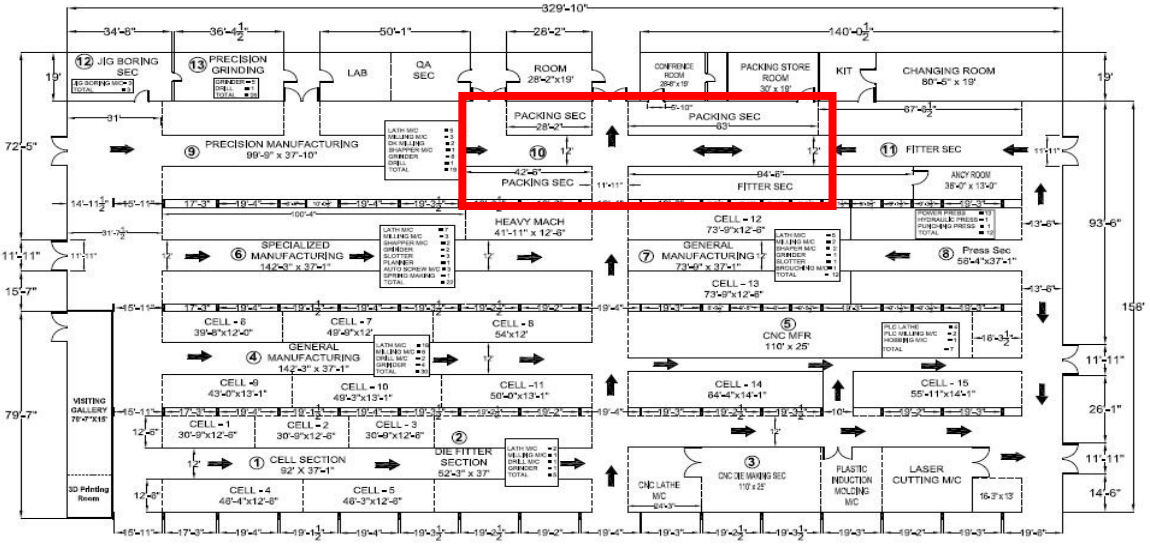


Figure 16: Layout of Packing Section

installed in this section as per requirements. Packing box also available in this section. Before packing proper quality, check done by QAD section and fill-up remark sheets. In this section 4 person required to manage packing and record keep of the parts.

4.5.11 Fitter Section:

Section in bay 4 of manufacturing group is fitter section. In this section all types of parts and dies developed which required fitment of two or three more parts done. In fitter section some tables and welding plants installed for fitting works and there are 4 machines also install in this section which are shearing machine, and three small size bending machines. Centre path connects this section with packing section and with exit gate. Fitter section designed after the discussed with the workers, supervisor and management therefore in this process the workers taking ownership for decision.

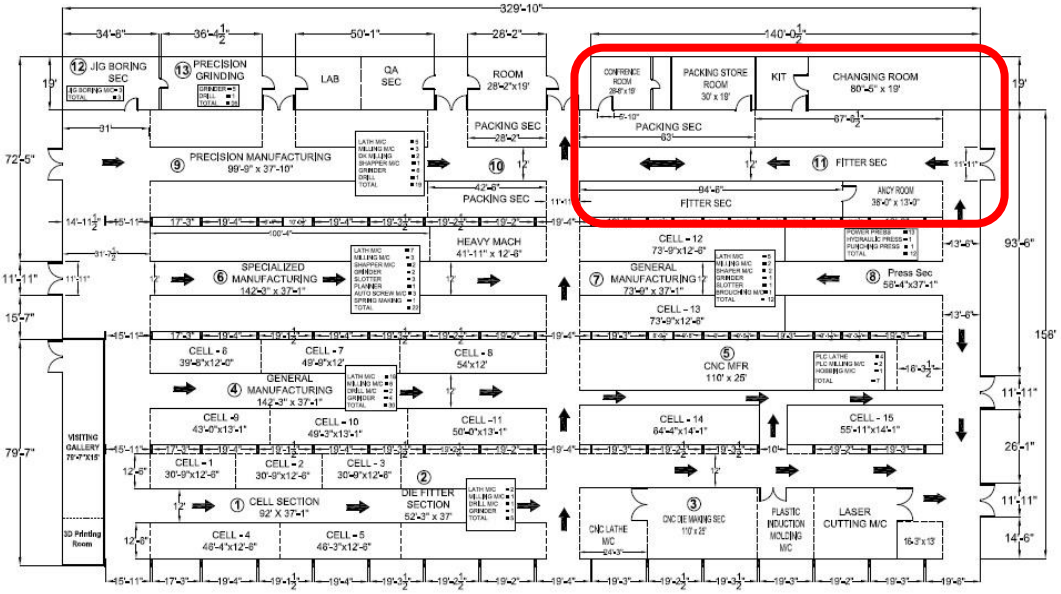


Figure 17: Layout of Fitter Section

4.5.12 Jig Boring Section:

Some sections and stores built inside room of manufacturing group. These are stores, QAD office, Lab, staff room, precision grinding, jig boring section and 3D printing room. This section is called the jig boring section of the manufacturing group. In this section 3 large size machines installed. Two out of three machines are vertical jig boring machine, and one is horizontal boring machine. These all-machine use in production of boring purposes. Jig boring is used to accurately enlarge Previous holes and make them

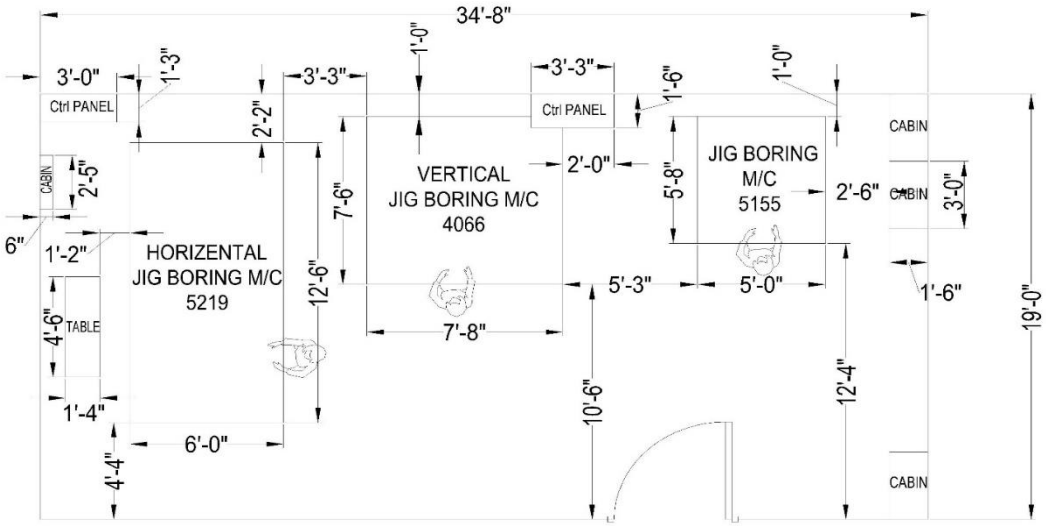


Figure 18: Layout of Jig Boring Section

diameters highly accurate. Typically, a part has holes machined on regular equipment and then the part is transferred to a dedicated jig boring machine for final operations on the especially accurate holes. For this section entrance provide from bay 4. For high accuracy this section is separate from other section. In this section 3 person required to manage all boring machines. Work of this section is very important therefore the layout and working procedure has designed with involvement of workers, supervisor and management.

4.5.13 Precision Grinding Section:

This section is called precision grinding section which is also high accuracy job. Precision grinding is a precise manufacturing process used across a diverse range of sectors, providing an efficient way to complete the fabrication, and finishing of metal parts with very close and tight tolerances. In manufacturing group this section uses for production of gauges. These gauges require high accuracy and finishing in range of very less tolerance. This section also inside room of manufacturing group. And bricks wall separates this section from other sections. Because precision grinding also require close environment for working. Entrance of this section is also from bay 4 but separate from the jig boring section. In this section 6 person required to manage the work.

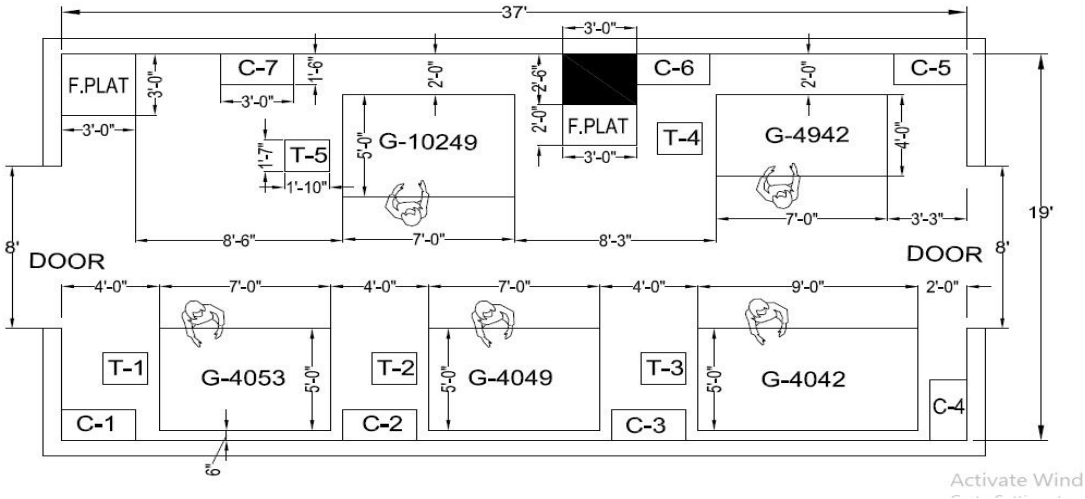


Figure 19: layout of Precision Grinding Section

4.5.14 Lab:

Different testing equipment's used in lab for material testing. Different tests perform in lab like Strength, material properties, torsion, load capacity, density etc. of required materials. Aims to prepare workers with the knowledge and ability to improve, evaluate, design and control safe, sustainable, and cost-effective technologies to make innovative and useful contributions to humanity. Arranged the training for workers and supervisor for use of lab equipment because after the training the worker has been used the lab equipment in proper way and efficiently. Mechanical engineering lab equipment include strength of materials lab equipment. In this lab different types of equipment available like applied mechanics lab equipment's, hydrology lab equipment's, mechatronics lab equipment's, CAD/CAM lab equipment's, dynamics of machine lab equipment's, metrology lab equipment's, mechanical workshop lab equipment's and heat transfer lab equipment's.

4.5.15 Quality Assurance (QA) Section:

Quality assurance section also allocate in manufacturing group. By this section control on parts and material quality and before packing and delivering the parts quality assurance department check and verify quality of the parts by their rules and standards. **Quality Assurance (QA) is** defined as an activity to ensure that an organization is providing the best possible product or service to customers. QA focuses on improving the processes to deliver Quality Products to the customer. An organization must ensure

that the processes are efficient and effective as per the quality standards which can be defined as an international standard. Quality Assurance is popularly known as QA Testing.

4.5.16 3D Printing Room:

Innovation and finding new ways to do things in a smarter and more efficient way is necessary for organizations to stay competitive in an increasingly demanding environment. One such innovation is additive manufacturing (AM) also known as 3D Printing. This emerging technology is receiving increased attention and appears to embody a technology push, now that the number of applications is growing in an area that used to be predominantly focused on creating rapid prototypes. This innovation, and the speculated possibilities AM offers, are what stimulates businesses to consider adopting the technology. 3D printing room supports the whole group manufacturing requirements. 3D Printing is also used for the development of new parts. It is also used for costly and sensitive parts which cannot be available in the market at a reasonable price.

4.5.17 ANCY Room:

These is small area which is allocated by the name of ANCY room. In this room all type of welding work done. Small electric arc welding plants are portable type. By the requirement in all sections these plants provided on demand. Gas welding plant also available in this room. There are two other types TIG and MIG welding plants which are also available in this section. This room does not have separate boundary wall or any type of divider. In this section 4 person required to manage the work of welding and other work. In this section welding work performed, that the safety in work more important therefore arranged the training for the workers on personal safety and the use of personal safety equipment and make sure every worker of manufacturing shop 1 & 2 know the safety procedure during the work.

4.5.18 Changing Room/Staff Room:

All changing room which was built in different places in group are convert into combine staffroom. In the staffroom, the small kitchen available for labour or workers. Also, in staffroom space for rest provide for workers. when workers took break form the work then stay here for rest and refreshment.

4.6 Comparison of Previous and Designed Layout of Manufacturing Shop 2:

Previous layout was very complicated due to their workflow. There was no proper paths identification and material flow paths. Due to machines installed not in proper way as recommendation of new production system and Lean manufacturing procedures wastages was so much. Machines are installed in different sections by their working. Which was main cause of wastages of time and materials. For mass production there was no CNC manufacturing section which increases productivity and reduce time and cost of the material and manpower. Linkages between sections was not enough for large scale production. Less number of entrance and exist gates was also directly affecting the material flow which reduce the production. Many machines were not in use due to their installed location. Some machines need maintenance to start again for working.

Figure 20: Before Implementation

Designed layout solves many Previous problems of manufacturing and proposed production increasement procedures and techniques to reduction of wastages and increase production in less time.

Main manufacturing section is divided into small sections which represent their works. Specific machines of these sections were installed. CNC machines increased productivity and quality of the parts. Also reduced time of manufacturing which directly improve cost management. For material movement proper paths provide for lifters movement and linkage between all sections. Special purpose machines also installed into CNC manufacturing section which work on mass production of required parts. Proper quality checking system introduced to control quality to reduce material wastages. Quality assurance gate provides in every section on different stages which control in-house quality and then parts transfer to the packing section. Quality assurance check quality before packing and delivering the parts. General manufacturing sections divide into further small cells which include 3 lathes and 1 milling with separate drill and grinding machine. Work divided and completed in their respected cell. By these cell sections working progress also increased.

Figure 21: After Implementation

4.7 Advantages of Designed layout of Manufacturing Shop 2:

In Previous layout process flow was so complicated. Machining process were too much lengthy and time consuming. Too much manpower was required for different projects. Designed layout is based on the concept of "KANBAN" just-in-time process technique of production and "KAIZAN" lean manufacturing technique by proper use of these techniques, wastage control and efficient utilization of material were addressed. Designed layout defines sections which represent by there working. The use of Work in process (WIP) inventory concept reduced the inventory and its cost. Lifter move easily in group because proper paths are designed for material handling. LP store controlled the movement of local purchased items between sections. By reducing the rolling out time of parts on machines, reduced expenses of resources like over-production, time, electricity cost, manpower etc. The use of drawing helped machining section that controlled many loses like wastage of metal, wastages of time, control over-production and reduce electricity cost. Overall advantages of designed layout controlled over production, elimination of wastages, production costs, production time, machining time, fabrication time, items and parts movement, electricity cost saving and managing process flow easily. Process flow charts were provided along with the process sheets of the required parts to operator to follow proper steps to manufacture the required parts.

4.8 Comparison of Previous and Designed Layout of Manufacturing Shop 1:

4.8.1 Process Flow:

Previous layout process flow was so complicated. Fabrication and machining process were too much lengthy and time consuming. Too much manpower was required for Fire Fighting Vehicle and Water bowzer projects. After entering vehicle on Assembly line, all work was done on one Bay because of too much rush in fabrication and on assembly line. They take measurement for water tank of Fire Fighting Vehicle. Then Sheets are issued from metal store and then, are taken to the welding section for cutting and welding purposes. Then water tank is moved near to the vehicle. Same process on water was performed on bowzer project. All fabrication jobs performed on stage and parts movement from LP store and Machining section affected by fabrication work on assembly lines.

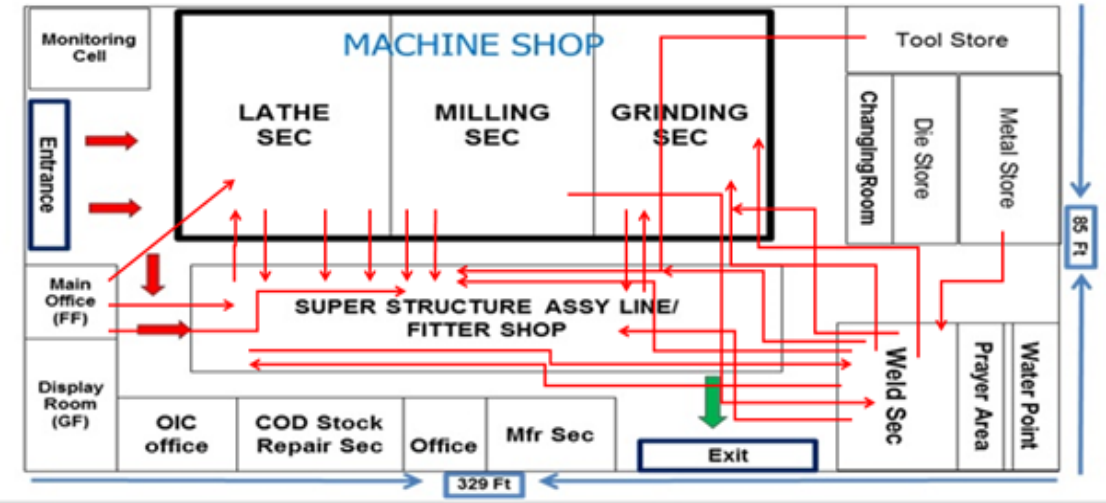


Figure 22: Previous Process Flow Layout of Manufacturing Shop 1

In Designed Layout same as Previous layout one entrance was used for both Fire Fighting Vehicle and Water bowzer vehicles. But assembly line was divided into two assembly lines. Disassembly area was shifted outside the Manufacturing Shop 1 to reduce the load on the assembly line and work performed on this area is called stage zero. Assembly line one for Fire Fighting Vehicle projects and assembly line 2 for Water bowzer. Fitting stages was divided into small stages which contain process vise working. For Fire Fighting Vehicle project assembly line is divided into 8 Bays. When first project vehicle reaches on last Bay then on same time every Bay has occupied by project vehicles and under work by stage levels. Same line that water bowzer assembly line was divided into 7 Bays. All bays are kept occupied during projects. Two separates

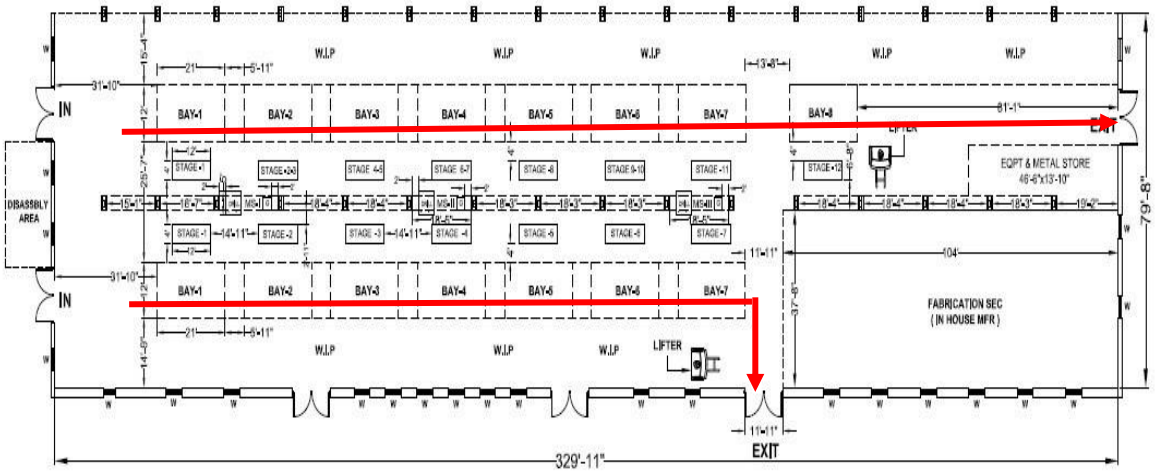


Figure 23: Designed Process Flow Layout of Manufacturing Shop 1

exit gates designed for Fire Fighting Vehicle and water bowzer. Main machine and fabrication section sifted to end right corner of the group. Also, three small machine stations designed for stage level operations which contains 3 machines per station.

All type of machining and fabrication work done in machine and fabrication section and no fabrication work will allow on work stages. Proposed wide space on the one side of both assembly line for WIP (work in process) inventory which comes from fabrication section by lifter. Only 16 machines were designed for machine section and 2 jigs for fabrication section. Fabrication section was divided into 4 parts (water tank section, water bowzer tank section, fabrication section 1 and section 2). Fabricated parts were shifted from the fabrication section to WIP space with the help of lifters. Local purchase items were shifted to related stage table from LP store. One table was allocated to every Bay. The process flow is now very simple and understandable.

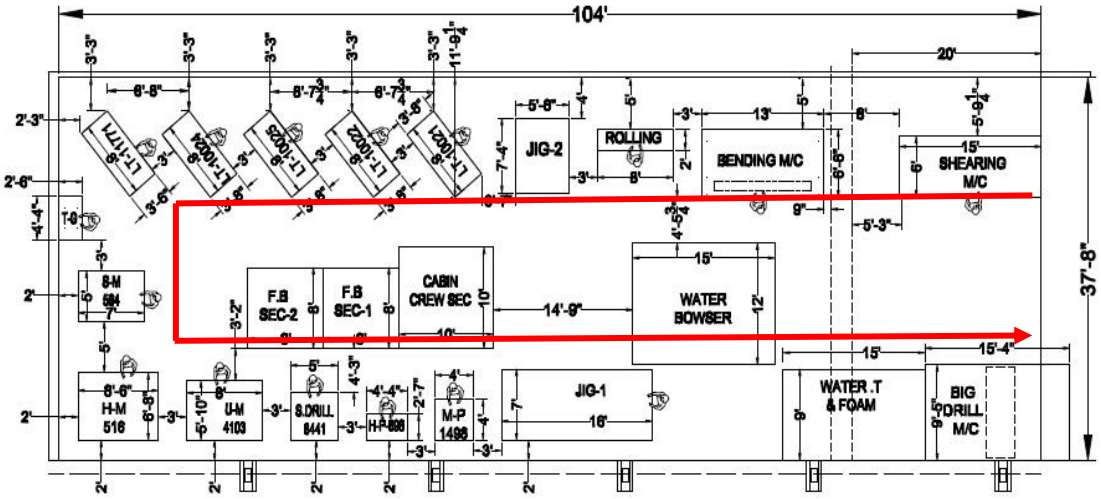


Figure 24: Designed Layout Fabrication Section of Manufacturing Shop 1

In previous layout workers were not following the process flow chart because the process flow chart concept is not used on every machine in every stage. In designed layout the process flow chart for operations on machines has helped workers and achieved the product quality according to requirement and cost efficient. Every worker knows about process sequences. Process flow chart describe the workflow of the product. Problems and rejections in operations has been traced with help of process flow chart. Quality of the product and calculation the time to completion of the product is easy with the use of process flow chart[41].

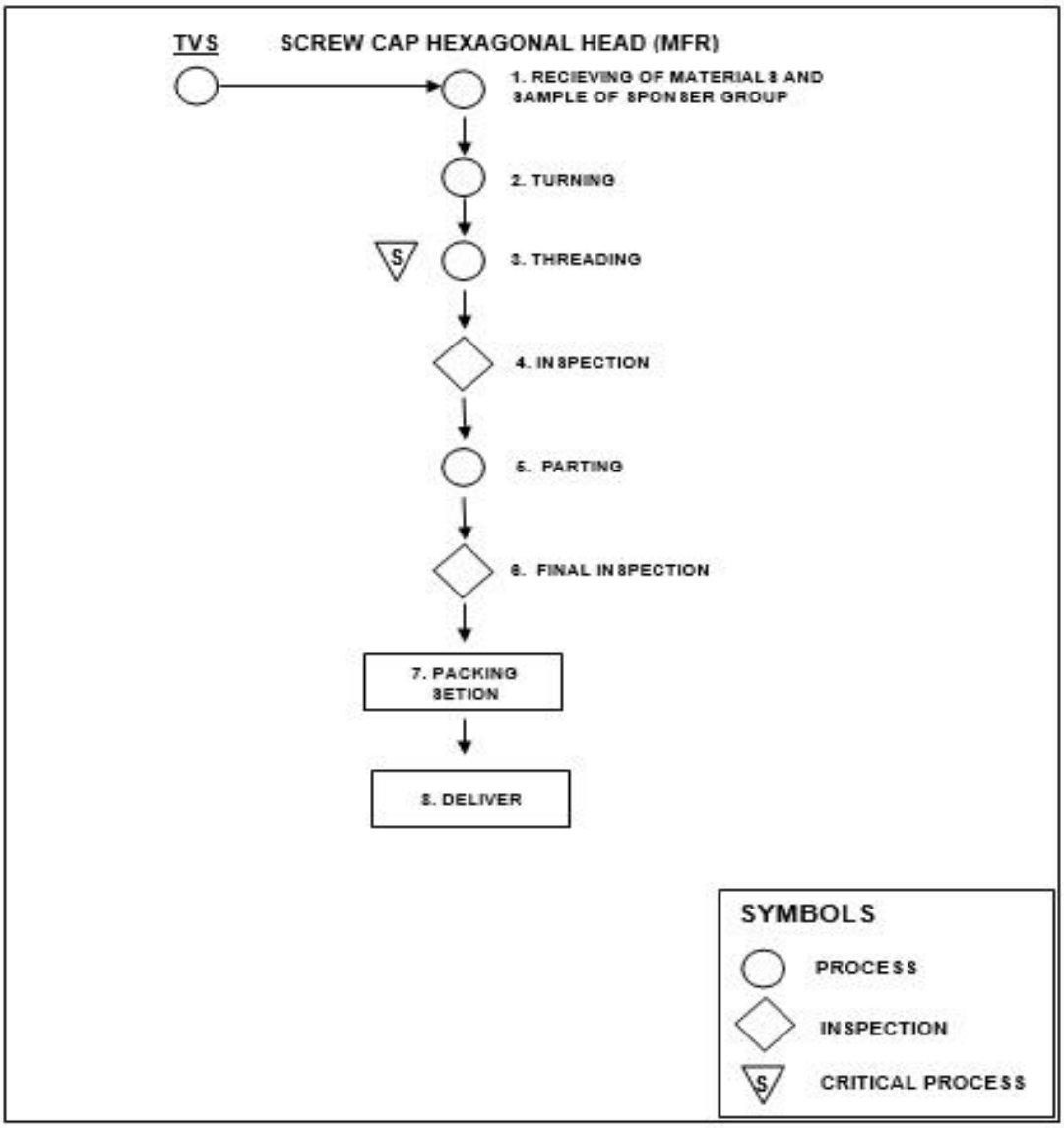


Figure 25: Process Flow chart

In process flow chart different symbols are used for different actions like circle, square and triangle. These symbols show different actions which are performed by workers on machines like circle means operations perform on the machine, square means quality check that was performed on critical operation specifically and triangle means critical process. The quality must be checked after every critical process as quality is most important for organization in competitive environment.

4.8.2 Roll-out Time:

Previous roll out time for a single Fire Fighting Vehicle project, it was taking 29 days to roll out the first vehicle and then after every 8 days rolling out vehicles from the assembly line. One day means is eight working hours in an organization. After removal of the gearbox for PTO gearbox fitment, the vendor was taking a time of 10 to 15 days. After that time vehicle was entering the assembly line. Where the vendor fitted the gearbox along with the PTO gearbox. Which was taking approximately 1 day. At the same point fabrication and fitment of the pump and foundation takes place. Fitment and fabrication of PTO shafts and fitment of pump foundation was taking 2 days and fabrication and fitment of the water tank take 2 days. Fabrication of crew cabinet and fitment of crew cabinet and other accessories was taking 2 days. Fabrication of water tank side walls, foam tank and mudguards and their fitment were taking 3 days. Fabrication of crew seats, accessories rack and hangers of suctions pipes and fitments of these parts was taking 3 days. The fitment of all pipes of the water tank, foam tank deliveries and suctions lines were taking 3 days. the fitting of monitoring guns and water tank filling line was taking 2 days. On the assembly line fabrication of pump cabinet and fitting of pump cabinet was taking 2 days. The cutting of pump cabinet sheets, back door fabrication, fitting of back door and locks was taking 2 days. The fitting and fabrication of roof sheet and roof reeling was taking 1 day. The Fitment of revolving lights and other accessories was taking one day. In the end, auto wiring was taking 2 days. After completing the assembly of the vehicle, conduct the in-house trial which was taking one day to test the leakage of the tank and PTO gearbox working. After the in-house trial, the paint work started in another group because the paintwork

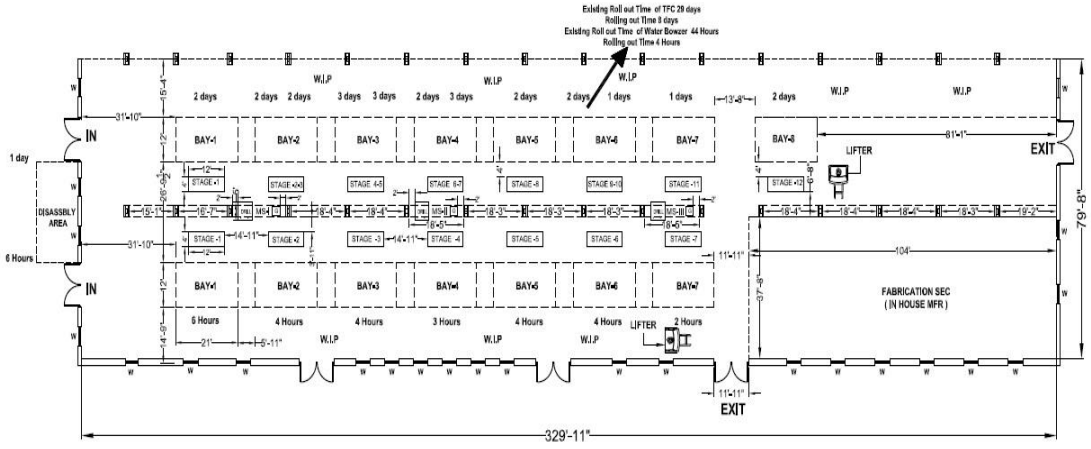


Figure 26: Previous Roll out Time of Manufacturing Shop 1

facility was not the in-assembly line therefore the 2 days were required to complete of work. The rollout time of the first vehicle was 29 days and then the rolling out time was 8 days. In previous Rollout time of water bowzer was 44 hours of 1st vehicle and rolling out time was 5 hours. The time required is 6 hours to perform the work of stage zero which is called the first stage. At stages 1 and 2 the time was required to perform the work 4 hours on each stage. At stage 3, the time was required 4 hours to perform the work. At stage 4, the time was required 3 hours to perform the work. At stages 5 and 6, the time was required 6 and 4 hours respectively to complete the work. The required time was 3 hours at stage 7 to perform the work. 5 hours was required to complete the work on stage 8. The time was required 5 hours to perform the work on stage 9.

The designed rollout time of Fire Fighting Vehicle is 34 hours and then after every 3 hours, the Fire Fighting Vehicle is out from the assembly line. For water bowzer project rollout time is 31 hours and then after every 3 hours the water bowzer rolling out from the assembly line. At stage zero the pump foundation has issued from Fabrication Section. The required time to install is 5 hours. PTO shaft and pump issued from LP Store and the time required to installed is one hour. At stage 2, the fitment of additional chassis and water tank has installed, which has received from the fabrication section. whole work done according to the fabrication drawing. To perform this task, it takes 2 hours. At stage 3, the fitment of crew cabin and shutter gate installed which is fabricated in fabrication section. It is takes 2 hours to performed. At stage 4, the fitting of sidewalls, foam tank and mudguards has performed, which were completely fabricated in the fabrication section. It is takes 2 hours to performed. On stage 5, the fitting of crew seats,

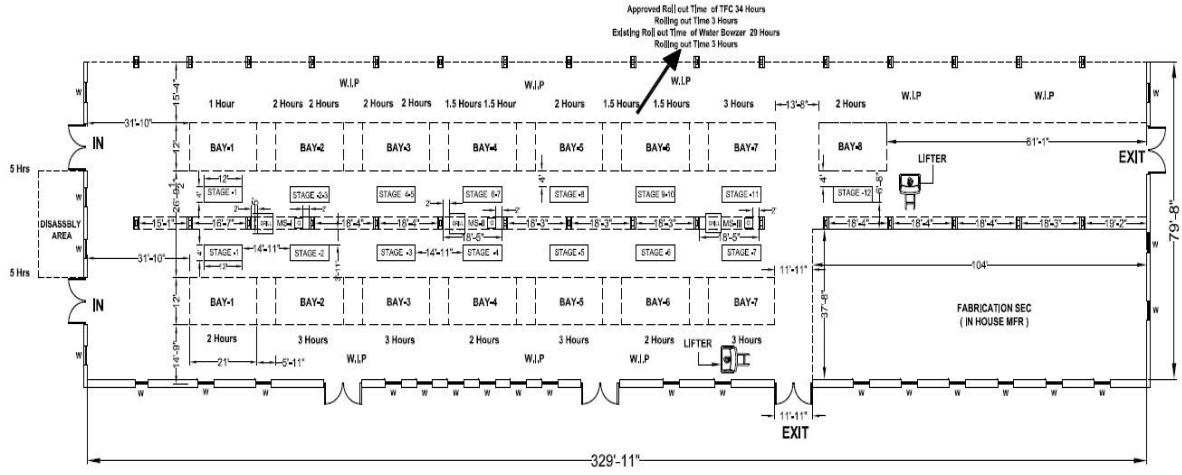


Figure 27: Designed Roll out Time of Manufacturing Shop 1

On stage 5, the fitting of crew seats, accessories rack and hanger of the suction pipe to performed, which is completely fabricated and machining in the respective section. This work was performed in 2 hours. On stage 6, the fitting of water & Foam lines has done which is fabricated and installing in proper size according to the drawing. It is performed in 1.5 hours. Stage 7, the fitment of the monitoring has done according to the assembly drawing. Monitoring Gun issued from the L.P store and it is taken 1.5

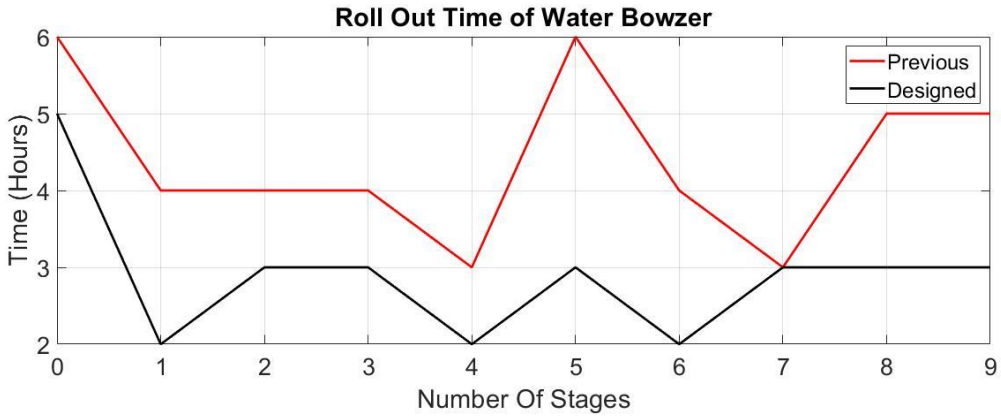


Figure 28: Comparison of Roll out Time (Fire Fighting Vehicle)

hours. On Stage 9, the fabrication and fitting of the pump cabinet were done according to fabrication and assembly drawing, this work has been performed work in 2 hours. On Stage 9, the fitment of the pump cabinet sheet was done which is fabricated according to the fabrication drawing in the fabrication section. It has been performed in 1.5 hours. The riveting of the sheet on the rooftop has done according to the drawing on stage 10 which is fabricated according to the drawing in the fabrication section. This work is performed in 1.5 hours. At Stage 11, the fitting of the roof railing was casted

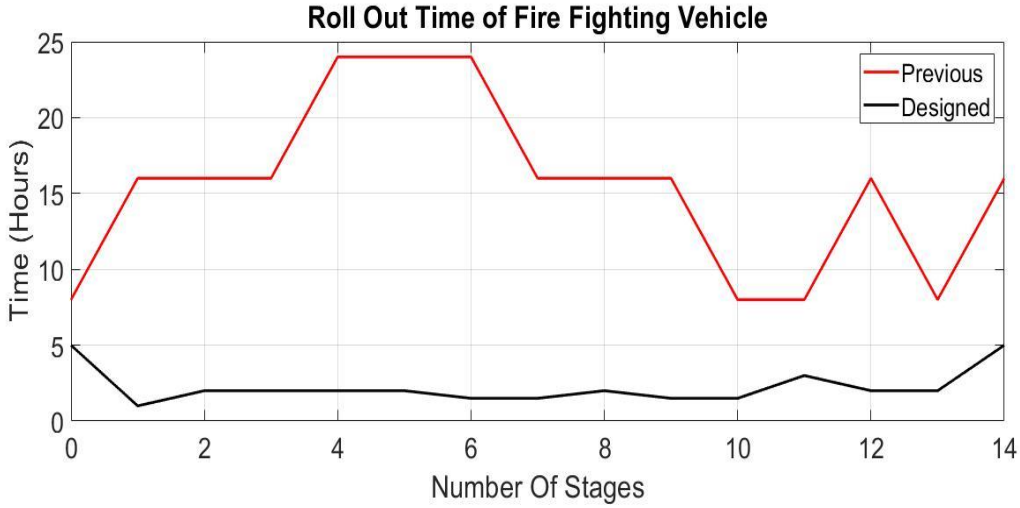


Figure 29: Comparison of Roll out Time (Water Bowzer)

from the outsourcing of the group. The machining process has been performed in the machining section according to the drawing. This work has performed in 3 hours. At Stage 12, the auto wiring and fitment of accessories were done according to the electrical wiring drawing. The work has been performed in 2 hours.

4.8.3 Manpower:

In previous setup the Fire Fighting Vehicle and Water Bowzer is main project of General Manufacturing Shop 1. Small toeing water tank and other small projects are carried out in this shop. 135 persons worked in this shop including management staff. Approximately 76 persons was worked on previous projects of Fire Fighting Vehicle and 43 persons worked on Water bowzer projects. The fabrication and machining section was worked performed by 10 persons. Stage zero performed outside the workshop that were completed with 5 persons. At stage 1, the fitment and fabrication of PTO shafts and pump foundation was completed by 3 persons. At stage 2 Fabrication and fitment of the water tank were done by 4 persons. Fabrication of crew cabinet and fitment and other accessories were needed 11 persons to perform this job at stage 3. Fabrication of water tank side walls, foam tank, mudguards and their fitment done by 7 persons at stage 4 of the assembly line. At stage 5, the fabrication of crew seats, accessories rack, hangers of suctions pipes and fittings of these parts were required 8 persons to complete. The fitment of all pipes of the water tank, foam tank deliveries and suctions lines were required 10 persons to complete the work at stage 6. The fitment of monitoring guns and water tank filling line at stage 7 were required 2 persons. On the assembly line fabrication of pump cabinet and fitment of pump cabinet at stage 8

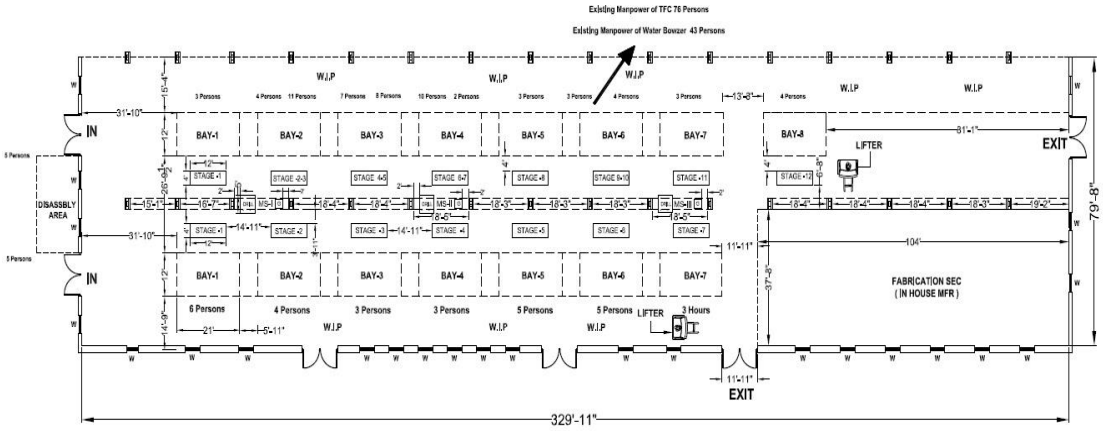


Figure 30: Previous Manpower of Manufacturing Shop 1

three persons were required to perform this job. Cutting of pump cabinet sheets, back door fabrication, fitment of back door and locks were required 3 persons to perform this job at stage 9. Fitment and fabrication of roof sheet and roof reeling were completed with 3 persons at stage 10. The fitment of revolving lights and other accessories at stage 11were required 4 persons for the work. 4 persons were required to complete the work on stage 12 for auto wiring. In previous setup of water bowzer, at stage zero 5 persons were required to complete the work. At stage 1 were required 6 Persons to perform the job. 4 persons was required to perform the work of stage 2. At stage 3 required number of persons were 3. To perform the work on stage 4 was required 3 persons. At stage 5, 5 persons were required to perform the work. Stage 6 and 7 required 5 and 3 persons respectively to perform the work.

The manpower reduced for Fire Fighting Vehicle project from 76 to 45 persons on assembly line and for water bowzer from 43 to 30 persons. At Stage 1 Water Bowzer/Fire Fighting Vehicle is received from Stage Zero with the fitment of PTO gearbox. It has required 2 persons to perform this job. At Stage 2, the fitment of additional chassis and water tank, received from the fabrication section, it is done according to the fabrication drawing. Two persons perform this job on workstation. At stage 3, require 3 persons to perform the fitment of crew cabin and shutter gate. It is fabricated in the fabrication section according to drawings. At this stage 4 person required to perform this task. In this task the fitment of sidewalls, foam tank & mudguards, which has completely fabricated in the fabrication section. Fitment of crew seats, accessories rack, the hanger of the suction pipe, this fitment has completely

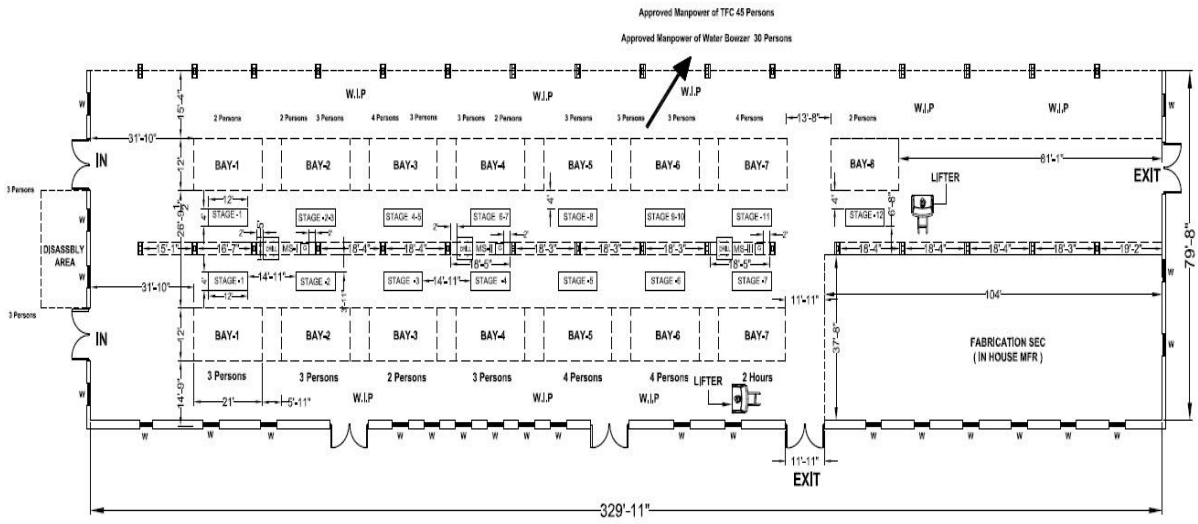


Figure 31: Designed Manpower of Manufacturing Shop 1

fabricated and machining in fabrication section. At stage 5, the work has performed by 3 persons. At stage 6, the fitment of water & Foam lines has done which makes according to the drawing.

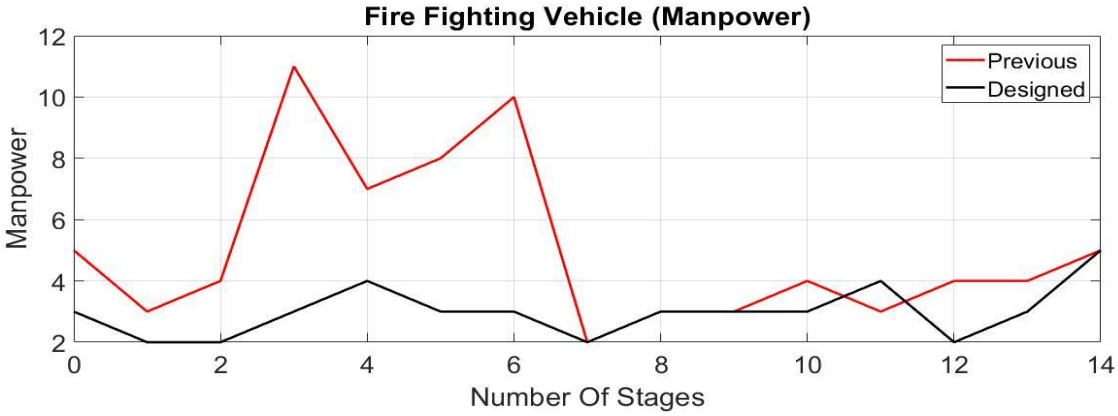


Figure 32: Comparison of Manpower (Fire Fighting Vehicle)

This task performed by 3 persons. At stage 7, the fitment of the Monitoring Gun has done according to the assembly drawing. Monitoring Gun issued from the L.P store. This work has required 2 persons. The fabrication and fitment of the pump cabinet done according to fabrication and assembly drawing at the stage 8, which has been required 3 persons. On stage 9 fitment of the pump cabinet sheet will completed, which are fabricated according to the fabrication drawing in the fabrication section and this task required 3 persons. On stage 10, the riveting of the sheet on the rooftop has done according to the drawing which fabricates according to the drawing in the fabrication section it is performed by 3 persons. Fitment of roof railing, revolving light and side stairs at stage 11 performed by 4 persons. Auto wiring and fitment of accessories was performed by 2 persons on stage 12.

In case of water bowzer at stage 1 required 3 Persons to perform the job. 3 persons is

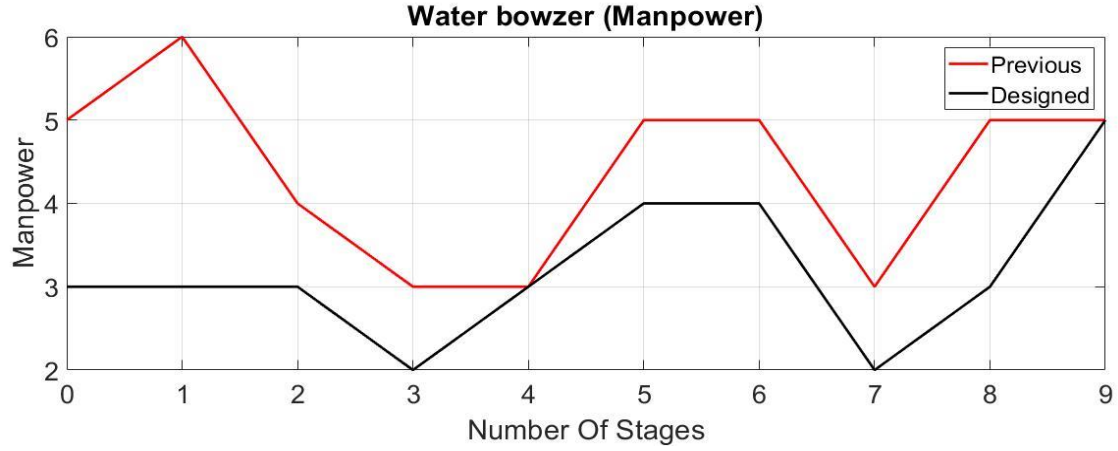


Figure 33: Comparison of Manpower (Water Bowzer)

required to perform the work of stage 2. At stage 3 required number of persons is 2. To perform the work on stage 4 is required 3 persons. At stage 5, 4 persons are required to perform the work. Stage 6 and 7 required 4 and 2 persons respectively to perform the work.

4.9 Advantages of Designed Layout of Manufacturing Shop 1:

In Previous layout process flow was so complicated. Fabrication and machining process were too much lengthy and time consuming. Too much manpower was attached with Fire Fighting Vehicle and Water bowzer projects. Designed layout is based on the concept of "KANBAN" just-in-time process technique of production. By use of designed layout time of assembly of Fire Fighting Vehicle and water bowzer reduced from 8 days to 3 hours for Fire Fighting Vehicle. Are allocate for Work in process (WIP) inventory which reduced the time of fabrication and fitment time. The lifter movement has been made easily beside the assembly lines. LP store controls the movement of locally purchased items between the stages. Metal stores allocated near to the fabrications have reduced the time and cost of heavy metals. Vehicles movement between the working stations reduced the time of fitment. By reducing the rolling out time of vehicles on assembly lines has reduced expenses of resources like over-production, time, electricity cost, manpower etc. Drawing helped to machining and fabrication section to produce items which have controlled many losses like wastage of metal, saving time to get measurement, control over-production, and reduce electricity cost. Three machine stations in between the assembly lines have provided easy access to the fitters for work on machines. In the designed layout process flow is very easy and understandable. LP store deals with stages, metal store attaches with fabrication and machining section. The lifter controls the WIP inventory for the Fire Fighting Vehicle and for Water bowzer Assembly line. Zero interruption has been achieved through a designed layout between stages or working stations and the fabrication and machining section. Overall advantages of the designed layout are controlled overproduction, elimination of wastages, production costs, production time, machining time, fabrication time, items and parts movement, electricity cost-saving and managing process flow easily. The manpower was reduced by 30% and roll out time is reduced by 34%. This reduction helps to make Manufacturing Shop 1 more productive and efficient.

4.10 Fire Fighting Vehicle Assembly Line

4.10.1 Stage 0

Work of assembling Fire Fighting Vehicle starts with the disassembly of the gearbox by the vendor. This area where this work is performed, called Disassembly Area is situated outside the Workshop where the Vendor removes the gearbox from the truck and takes away the gearbox to its own shop for further process, which may take 10-15 days. When PTO Gear is ready for assembly, it is assembled with gearbox and brought back to the workshop and fitted into Fire Fighting Vehicle. PTO or power take-off is a device that takes power from one source and gives it to another thing that does not have its source of power. One of the main reasons for slow production is this process which takes days before Fire Fighting Vehicle is handed over to the main assembly line of the workshop. And one more problem that has been observed here is that there are no standard protocols to check and verify the quality of the work done by the vendor. As per the Previous plan, it took 5 persons and 1 day to perform, the same operation which could be performed by 3 persons in 5 hours as proposed.

4.10.2 Stage 1:

At Stage 1 Fire Fighting Vehicle is received from stage zero with the fitment of PTO gearbox. At this stage Pump foundation, issued from Fabrication Section, PTO shaft and Pump, issued from LP Store, are installed. After this fitment delivery lines of Pump are welded. Spanner set, hand drill, and welding plant are required for work on this stage. Bay 1 is dedicated to performing operations relevant to stage 1 of the assembly line. When the functionality of the stage is compared with the previous working plane of stage One, gaps were found which were resulting in wastage of time and other relevant resources. Previously 3 personnel were required to perform the same operation, which consumed two working days while the designed layout reduced the required personnel and time to 2 and 1 hour respectively. Previously no drawings or SOP’s were considered or followed for fabrication and assembly of parts, now drawings/SOPs issued or fabrication and assembly of each part as a standard protocol which resulted in improved quality o product and better understanding of the work that would be performed by the workers.

4.10.3 Stage 2:

At this stage fitment of additional chassis and water tank, which has been received from the fabrication section. The fitting of these items is completed according to drawings to maintain quality. Welding plant, spanner set are the required tools for this working. When compared with the Previous Work Plane, gaps were identified which were causing the wastage of time and resources. In the previous plan, most of the work was performed on the Assembly Line. It took 4 workers in 2 days to perform this task while now it takes 2 persons and 2 hours to perform the same task. Moreover, Previous drawings weren't detailed enough to perform these tasks. This issue has mitigated by providing new detailed assembly drawings.

4.10.4 Stage 3:

At this stage, the fitment of the crew cabin, shutter gate is completed which is fabricated in the fabrication section. Accurate sized, the cut sheet is received from the fabrication section and the riveting of the sheet is done at this stage. Welding Plant, Rivet Pillar, Hand Drill machine, Spanner Set are required tools at this stage. As per the previous plan, it took 11 persons in 2 days to perform the same operation now which was performed by 3 persons in 2 hours in the designed layout.

NOTE: Work of stages 2 and 3 performed on BAY 2

4.10.5 Stage 4:

At this stage, the fitment of sidewalls, foam tank & mudguards is completed which has been completely fabricated in the fabrication section, will be done by following the fabrication drawings. Welding plant and spanner set are required tools to complete the work at this stage. Fitment of sidewalls, foam tank & mudguards on this stage was performed according to the detailed assembly drawing. But as per the previous work plan, fabrication and assembly of sidewalls and mudguards were performed on the assembly line, and drawings were not followed which caused the wastage of time and other relevant resources. As per the previous plan, it took 7 persons in 3 days to perform the same operation, which has performed by 4 persons in 2 hours in the designed layout.

4.10.6 Stage 5:

At this stage, the fitment of crew seats, accessories rack, the hanger of the suction pipe has been done, which is completely fabricated and machining in the fabrication and

machining section. Crew seats and accessories rack fabricated from the fabrication section. Work completed according to the fabrication drawings. The hanger of the suction pipe casting is outsourced, and machining of these casted items is done according to the drawing. Spanner set, welding plant, hand drill machine and taps required to complete the working at this stage. As per the previous plan, it took 8 persons in 3 days to perform the same operation, which can perform by 3 persons in 2 hours as per design.

NOTE: Work of stages 4 and 5 performed on BAY 3

4.10.7 Stage 6:

At this stage, the fitment of water & Foam lines has been done, which is made a proper size according to the drawing. Fitment of the suction line from tank to pump and foam mixing unit completed according to the proper size and detail assembly drawing. Welding plant, Hand Grinder, Spanner set and Pipe wrench which tools were used to complete the work on the stage. In the Previous-working layout, this work was not done according to the proper drawing and take a new measurement again and again on every new vehicle due to this work process the quality and accuracy of work was not maintained, according to work the process the fitment of the water tank and foam lines, which was causing the wastage of time and other related resources. As per the previous plan, it took 10 persons in 3 days to perform, the same operation which has performed by 3 persons in 1.5 hours according to the designed layout.

4.10.8 Stage 7:

At this stage, the fitment of the Monitoring Gun has been done according to the assembly drawing. Monitoring Gun issued from the L.P store. The fitment of tank filling lines was done according to the assembly drawing which was completed on the stage. Welding plant, spanner set, pipe Wrench and hand grinder are required to use to complete the work at the stage. In previous-working layout was not follow the assembly drawing and WIP (Work in Process) concept which was causing wastage of time. As per the previous plan, it took 2 persons in 2 days to perform the same operation which has performed by 2 persons in 1.5 hours in the designed layout.

NOTE: Work of stages 6 and 7 performed on BAY 4

4.10.9 Stage 8:

At this stage, the fabrication and fitment of the pump cabinet are completed according to the fabrication and assembly drawing at the stage. Welding plant, pipe cutter, spanner set, hand grinder, hand drill machine is required tools to complete the work. In previous work layout does not follow the drawing which was causing the wastage of time. Moreover, Previous drawings weren't detailed enough to perform these tasks. This issue was mitigated by providing new detailed assembly drawings. As per the previous plan, it took 3 persons in 2 days to perform the same operation which has performed by 3 persons in 2 hours in design layout.

Note: BAY 5 is used for stage 8 process

4.10.10 Stage 9:

In this stage fitment of the pump cabinet sheet has done, which are fabricated according to the drawing in the fabrication section. The fitment of the back door, which has bended according to the drawing in the fabrication section. Welding plant, hand grinder, hand drill machine, rivet pillar is required to complete the work at the stage. In previous layout were not follow the drawing which was causing the wastage of time. Moreover, previous drawings weren't detailed enough to perform these tasks. This issue mitigated by providing new detailed assembly drawings. As per the previous layout, it took 3 persons in 2 days to perform the task on the stage, the same operation which is performed by 3 persons in 1.5 hours in designed layout.

4.10.11 Stage 10:

At this stage, the riveting of the sheet on the rooftop has done according to the drawing which has fabricates according to the drawing in the fabrication section. In previous work, the layout was not following the drawing which was causing the wastage of time. Moreover, previous drawings weren't detailed enough to perform these tasks. This issue resolved by providing new detailed assembly drawings. Hand drill machine, rivet pillar is required to complete the work at the stage. As per the Previous plan, the fitment of roof railing was combined with the previous stage which was increasing the time of the stage therefore one day required with the help of 4 persons. This work performed by 3 persons in 1.5 hours in designed layout.

NOTE: Work of stages 9 and 10 performed on BAY 6

4.10.12 Stage 11:

At this stage, the fitment of roof railing which is received from outsourcing. It was made by casting process which was not available in this group. Machining process was performed in the machining section according to the drawing. The fitment of revolving lights completed which was issued from the L.P store. The fitment of stairs has done which was fabricated from the fabrication section according to drawing. Spanner set, hand drill machine and rivet pillar are required to perform the work on the stage. In previous work, the layout was not following the drawing which was causing the wastage of time. Moreover, Previous drawings weren't detailed enough to perform these tasks therefore the time was required is one day with 3 persons. This issue minimized by providing new detailed assembly drawings. The work has performed by 4 persons in 3 hours in designed layout.

NOTE: BAY 7 has used for the work of stage 11

4.10.13 Stage 12:

At this stage, auto wiring and fitment of accessories has done according to the electrical wiring drawing. Moreover, Previous drawings weren't detailed enough to perform these tasks. This issue mitigated by providing new detailed drawings. Whole accessories were issued from the L.P store. Spanner set, tester and pillar are required to complete the work on the stage. In previous work, the layout was not following the drawing which is causing the wastage of time therefore the time required to finish the work on the stage is 2 days with 4 persons. but in designed layout this work performed by 2 persons in 2 hours. In the previous layout, this work was combined with the previous stage that this is the reason to increase the time of the project.

NOTE: BAY 8 has used for the work of stage 12

4.10.14 Stage 13:

At this stage, the in-house road trail was performed outside the workshop after completion of the assembly. The testing and inspection team was checked the leakage of the water tank and PTO gearbox problems. They also check other accessories and water pump delivery pressure. Spanner set, pipe wrench and measuring tap are required to perform this Testing and Inspection process. It has taken 3 persons 2 hours to perform this operation. But in the previous layout, this vehicle trail was taking 1 day with 4 persons.

4.10.15 Stage 14:

At this stage, the paintwork outsourced after completing the in-house trail. The required time for paintwork is 5 hours and 5 persons. Because as per the previous plan this operation was performed by 5 persons in 2 days.

4.11 Stages of Water Bowzer

4.11.1 Stage 0:

Water Bowzer start with the disassembly of the gearbox by the vendor. This area where this work is performed, called Disassembly Area is situated outside the Workshop. Where the Vendor removes the gearbox from the truck and takes away the gearbox to its own shop for further process, which may take 10-15 days. When PTO Gearbox is ready for assembly, it is assembled with gearbox and brought back to the workshop and fitted into Bowzer. One of the main reasons for slow production is this process which takes days before Bowzer is handed over to the main assembly line of the workshop due to vendor. One more problem that has been observed here is that there are no standard protocols to check and verify the quality of the work done by the vendor. As per the previous plan, it was taking 5 persons and 6 hours to performed, the same operation which has performed by 3 persons in 5 hours in designed layout.

4.11.2 Stage 1:

At this stage, the fitment of the water tank on vehicle chassis has done according to assembly drawing. which is completed fabricated in the fabrication section according to the drawing. Moreover, Previous drawings weren't detailed enough to perform these tasks. This issue has overcome by providing new detailed assembly drawings. Spanner set is required to complete the work on the stage. In previous layout was not following the concept of WIP (work in process) which was the reason the wastage of time. As per the previous layout, it was taking 6 persons 4 hours to perform, the same operation which has performed by 3 persons in 2 hours in designed layout.

NOTE: BAY 1 has used for the work of stage 1

4.11.3 Stage 2:

At this stage, the fitment of the fabrication of the foundation of the pump, mudguard and protection grill has done, which was fabricate from the fabrication section

according to the fabrication drawing. In the previous layout, the plan was not following the drawing and work in process concept which is causing the wastage of time. Moreover, Previous drawings weren't detailed enough to perform these tasks. This issue will be mitigated by providing new detailed assembly drawings. Welding plant, hand drill machine and spanner set are required to perform the work on the stage. In previous work layout was not follow the drawing which was causing the wastage of time. As per the previous layout, it was taking 4 persons 4 hours to perform, the same operation which has performed by 3 persons in 3 hours in designed layout.

NOTE: BAY 2 has used for the work of stage 2

4.11.4 Stage 3:

At this stage, the fitment of the water pump and suction lines has been completed according to the assembly drawing. which was an issued from the L.P store. The previous layout was not following the drawings and work in the process concept which was causing the wastage of time. Moreover, Previous drawings weren't detailed enough to perform these tasks. This issue was mitigated by providing new detailed assembly drawings. Welding plant, pipe wrench and spanner set are required to perform the work on the stage. As per the previous plan, it was taking 3 persons 4 hours to perform, the same operation which has performed by 2 persons in 3 hours.

NOTE: BAY 3 has used for the work of stage 3

4.11.5 Stage 4:

At this stage, the fitment of delivery lines has been done on the stage which is according to the assembly drawing. In the Previous layout were not follow the drawings and work in the process concept which was causing the wastage of time. Detail drawings were provided to workers for working on this stage. A pipe wrench and spanner set are required to complete the work. It was taking 3 persons 3 hours to perform; the same operation has performed by 3 persons in 2 hours.

NOTE: BAY 4 has used for the work of stage 4

4.11.6 Stage 5:

At this stage fabrication and fitment of pump cabinet will be done according to fabrication and assembly drawing. In previous work plan were not following the drawing which was causing the wastage of time. Moreover, Previous drawings weren't

detailed enough to perform these tasks. This issue has been mitigated by providing new detailed assembly drawings. Welding plant and hand grinder are required to complete the work on the stage. The operation has performed by 4 persons in 3 hours as proposed. In the previous layout, it was taking 5 persons 6 hours to perform.

NOTE: BAY 5 has used for the work of stage 5

4.11.7 Stage 6:

At this stage, the fitment of the rear door, locks, stairs, and footrest has been done which is fabricated from the fabrication section. The previous work plan was not following the drawing which is causing the wastage of time because the fabrication of the rear door, lock, stairs, and footrest was on the stage. Moreover, Previous drawings weren't detailed enough to perform these tasks. This issue has been mitigated by providing new detailed assembly drawings. Welding plant, spanner set, and hand drill machine required to complete the work on the stage. As per the previous plan, it was taking 5 persons 4 hours to perform, the same operation which has performed by 4 persons in 2 hours.

NOTE: BAY 6 has used for the work of stage 6

4.11.8 Stage 7:

At this stage, auto wiring and fitment of accessories have been done according to the electrical wiring drawing. Moreover, Previous drawings weren't detailed enough to perform these tasks. Whole accessories were issued from the L.P store. Spanner set, tester and Pillar are required to complete the work on the stage. The previous layout was not following the drawing which was causing the wastage of time. The operation could be performed by 2 persons in 3 hours in the designed layout. As per the previous layout, it was taking 3 persons 3 hours to perform.

NOTE: BAY 7 has used for the work of stage 7

4.11.9 Stage 8:

At this stage, the vehicle completed from the assembly line to perform an in-house trail has outside the workshop on the road. The testing and inspection team checked the leakage of the water tank. They also check the water pump delivery pressure. Spanner set, pipe wrench and measuring tap are required to perform this testing and Inspection

process. It took 3 persons 3 hours to perform this operation in the designed layout. Because as per the previous layout this operation had performed by 5 persons in 5 hours.

4.11.10 Stage 9:

At this stage, the paintwork was outsourced after completing the in-house trial. The required time for paintwork is 5 hours and 3 persons. Because as per the previous layout this operation performed by 5 persons in 5 hours.

Chapter 5

Results and Findings

5.1 Conclusion

The lean manufacturing is a system in which we use different techniques to minimize the waste but on the other hand the goal of the system is to maximize the production rate with available resources to minimize the wastages. This technique is used to identify the value-added activities and non-value-added activities. Defects, over-processing, overproduction, excess motion, waiting, redundant transportation and futile inventory are the different sources of non-value-added activities, which can be a hurdle for value-added activities. Lean Manufacturing consists of soft and hard practices, it is used to increase the efficiency of the organization in terms of profit and quality of the product. Soft practices are related to human activities, when lean tools and practices are used with the help and coordination of workers in the pre-decision process of the organization, the effectiveness of the implementation increased, therefore, the importance of the human factor increased in the organization. The implementation effectiveness increased the motivation level through a reward and appreciation culture in the organization. Explain the responsibilities and duties of every employee. standardized the work through improving the process flow, use of detail and assembly drawings and use of quality checks on every stage of working. Involvement of workers, supervisors with management staff in a pre-decision process, that how to implement in lean manufacturing system in the organization. Quantitative research was conducted using a quasi-experiment to fill the knowledge gap of implementation of positive lean manufacturing in government organization of Pakistan automotive industry. Selected the assembly line and manufacturing section of the government organization to study the effects of the implementation of positive lean manufacturing in terms of motivation, Standardized work, identifying the duties and responsibilities of the workers in daily routine and coordination of workers in the pre-decision process. First, visited the assembly line and the manufacturing section of the organization. After visiting these sections, checked all the documents, observed the production process, process flow of the production, process flow chart on every stage, on every operation and noted the time of each process. Errors and omissions in the production process, flow of process, machines layouts, movement of workers during work, non-productive time of work,

quality process during the work and after the work completion, operation procedure and skills of workers have been noted on every stage of manufacturing shop 1 & 2. The daily, monthly and annually plan of production has given to the workers and showed some flexibility in plans execution. The discussed with shop supervisors and management staff for better plan. Every worker knows about plan which has been makes workers more punctual, committed and loyal with work. Discussed all points for effective implementation with shop supervisors, managers and workers, that how to motivate the worker and what steps take place. How to distribute the responsibilities and duties. How to standardize the work with use of understandable process flow, use of detail and assembly drawings and quality checks. Make the procedure of examine the whole process of improvement after some time with discussion, then make the plan to optimize the implemented improvements because every improvement needs to improve after the sometime. Give ownership of these improvements to workers for implementation which are suggested and discussed with workers. Collect data after implementation and compare data that was collected before implementation this data is in numerical form which is converted in coding form which is entered in MATLAB software for creating the "Plotting cool graph". After comparison, we have found a clear difference in production, utilization in manpower, material handling, layouts of the production process, process flow chart of operations on every stage.

5.2 Contribution

The results indicates that the implementation of lean manufacturing in government organization with involvement of workers increase the effectiveness of lean manufacturing system, which can ultimately cause increase in production. Increasing production also increases profits and enhances the organization's reputation in the market. The involvement of workers in the pre-implementation decision-making process increases the worker's loyalty and ownership towards implementation.

5.3 Practical Implication

This study will help to understand the importance of human factor in the implementation of lean manufacturing system in the organization thus encouraging the hidden skills in the lower-level workers which can be more useful for the reputation of an organization.

5.4 Study limitation

The study was conducted in a government organization in Pakistan. This does not include all public and private sector organizations. The work environment and the implementation of lean manufacturing may differ from other public and private organizations, so the results may vary for public and private organizations in Pakistan.

5.5 Future recommendations

In the future, the study will be conducted in other public and private organizations in Pakistan to find out the impact of the human factor in the implementation of lean. Training and seminars were conducted in the organization to train the upper management that how to motivate the workers, how to distribute the responsibilities and duties and how to develop the culture of improvement in the organization.

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