Addis Ababa University

Addis Ababa Institute of Technology

School of Mechanical and Industrial Engineering

MSc Thesis On: -

Assessment, evaluation and enhancement of operational performance of metal fabrication factory for cargo body, van body and trailer fabrication through lean practice (A case of KAKI PLC).

A Thesis Submitted to the School of Graduate Studies of Addis Ababa Institute of Technology, Addis Ababa University in partial fulfillment for the Degree of Master of Science in Mechanical Engineering (Manufacturing Engineering)

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Declaration

I hereby declare that the work which is being presented in this thesis entitled "**Assessment, evaluation and enhancement of operational performance of metal fabrication factory for cargo body and trailer fabrication through lean practice (A case of KAKI PLC)**" is original work of my own, has not been presented for a degree of any other university and all the resource of materials used for this thesis have been duly acknowledged.

__________________________ __________________________

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This is to certify that the above declaration made by the candidate is correct to the best of my Knowledge.

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Abstract

This study aims at investigating on assessment, evaluation and enhancement of the operational performance of metal fabrication factory for cargo body, van body and trailer fabrication by using lean practice at case company of Kaki PLC which is located at Addis Ababa around Sebeta (alemgena). The factory has a huge capacity but has a low operational performance and a large waste. The assessment and evaluation are performed on selected three major product types of the case company based on their demand volume and product nature. Using value stream mapping assessment of the current fabrication process of each product and identify the major waste of the company which are waiting time, defect, unnecessary movement and inventory and large setup time. During the investigation the data are collected by direct observation and using stop watch and the company document is also referred. Then by using cause and effect diagram, further analysis is conducted to identify the root causes for the bottlenecks which is found the poor layout of the factory.

The research work is proceeded to develop the solution standing from the assessment and evaluation result. The developed solution is designing new product lay out for three product mix namely NPR van, FSR cargo and trailer by using systematic layout planning, future value stream mapping as a model. In addition to product layout applying an oven in painting process and using simple press machine is the axle preparation in trailer fabrication process. Finally, the solution bring a significant operational performance improvement of the fabrication process of each product mix. The process efficiency of NPR van is improved by 25.4%, the process efficiency of FSR cargo improved by 31.9% and the process efficiency of trailer if improved by 32.42%.

To conclude this research work is conducted the assessment and evaluation process by using value stream mapping and cause and effect diagram and also using questioner. Then design new product layout for the factory using systematic layout planning. That will bring a valuable operational performance improvement.

Key words: performance, value stream mapping, key performance indicator, lean production, layout

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Abbreviation

SLP: Systematic Layout Planning

VSM: Value Stream Mapping

KPI: Key Performance Indicator

SMART: Strategic Measurement and Reporting Technique

BSC: Balanced Score Card

ABT: Actual Busy Time

APT: Actual Production Time

ADT: Actual Down Time

POT: Planned Operation Time

IQ: Input Quantity

RMQ: Raw Material Quantity

EMQ: Energy Medium Quantity

OQ: Output Quantity

DPQ: Desired Production Quantity

BPQ: By-Product Quantity

SQ: Scrap Quantity

AR: Allocation Ratio

UE: Utilization Efficiency

ELR: Equipment Load Ration

EPC: Equipment Production Capacity

PR: Production Rate

APSR: Actual to Planned Scrap Ratio

SR: Scrap Rate

EC: Energy Consumption

TPM: Total Productive Maintenance

DFT: Demand Flow Time

SMCD: Single Minute Change of Die

LM: Lean Manufacturing

TCR: Total Closing Rate

CORELAP: Computerized Relationship Layout Planning

WIP: Work in Process

PLC: Private Limited Company

Chapter One

1. Introduction

1.1. Background and justification of the study

Industry performance is conceptually defined with respect to its 'Key Performance Indicators' (KPI) e.g., lead time, cost, quality, efficiency, effectiveness and dependability, to be a function of independent concepts. It is a ratio of actual production achieved compared to the maximum production the factory is designed for. Industry performance can be used as the foundation for evaluating how a range of possible actions will impact profitability. The performance analysis measurement provides to, sustain or modifying the process or procedure to increase the output, increase efficiency, or increase the effectiveness of the process or procedure (Ali et al. (2014)).

Damtew et al. (2017) studied the performance of manufacturing industries in resource utilization, product quality, profit margin, sale growth, delivery time, in terms of achievement of demand and supply. Even though the market share, performance, GTP (Goods to People) contribution of basic metal industries has been poor analysis and evaluating the efficiency of an industry is essential for the overall organizational performance and competitiveness.

KAKI private limited company (PLC) was incorporated as a plc by 2003. Since its establishment the company has been making continuous growth and expansion by engaging in diversified business. Currently, KAKI is providing high quality products that are mainly tailored to import and export trading, manufacturing of dry land cargo bodies and parts, sesame, and cereal cleaning services, and dry Cargo transport services. The company is an official dealer of Isuzu trucks since 2017 GC. National Motors Corporation (NMC) was also an official dealer of Isuzu trucks. But, since 2021GC KAKI PLC become solo dealer of Isuzu trucks in Ethiopia.

The company has its own car assembly for Isuzu vehicles and metal manufacturing factory in addition to other business sectors. Metal manufacturing factory is equipped with different welding machine, overhead cranes, forklifts, Manito, cutting and bending machine, stand by generator and others and this factory are working for various cargo bodies mounted on Isuzu NPR, Isuzu FSR, Sino truck and trailer.

The sales volume of the company shows a continuous growth especially with in the last three years shows continuous increment. For example, the annual sales volume of 2010 EC is 702 units, 2011 EC is 871 units, 2012 EC is 619 units, 2013 EC is 665 units, and 2014 EC is 678 units (annual sales report of the company) as can see from this data and as of the company is solo dealer of Isuzu trucks it is simple to forecast that the sales volume will increase. However, as observed for the last five years the metal manufacturing factory has been running inefficiently for years and is rigid for change. It doesn’t have much confidence and willing towards innovation over old processes and the manufacturing process have different wastes like: -waiting time within the system, workers movement wastes, reworks and others. Hence resulting in low operational performance especially the products have a large production lead time and those things leads to dissatisfaction of customers especially by delivery date of the product. And also, the factory is working by far below from its capacity and the company misses the revenue that can collect from this sector. This limitation of existing techniques forces researchers to find a more comprehensive improvement technique to improve the operational performance of the case company. There are different number of methods for performance improvement like: -Total Production Maintenance (TPM), Lean Production, Demand Flow Technology (DFT) , Read a plant fast ,Simulation ,Process mapping ,Single Minute Change of Die (SMED) ,Five S (Grunberg (2007). For this research, lean production approach was selectively applied. Because lean production is the one which used to assess the entire operation system of such types of production system therefore this research work is this method as a tool. especially value stream mapping is used since it explains about the product value, the customer demand, the process flow, the material flow and the time taken in the process.

Lean is the integration of principles, practices, tools, and techniques to eliminate non-value-added activities. The elimination of those activities can improve both the cycle time and production lead time. The use of lean practice has been getting a special attention in several manufacturing industries to exceed the customers’ expectations by enhancing product’s quality, reducing production lead time, and minimizing costs (Gebeyehu et al. (2022). One of the most popular advanced manufacturing approaches is lean production. Organizations belonging to different business sectors throughout the world have implemented lean production concept in pursuit of increased organizational performance (Wickramasinghe (2017). Lean manufacturing or lean production, often simply "lean", is a systematic method for the elimination of waste (“mudu”) with in a Manufacturing system. Lean also takes into account waste created through overburden ("muri") and waste created through unevenness in workloads ("mura"). Lean manufacturing is now one of the most powerful manufacturing systems in the world (Natarajan et al. (2017).

1.2. Statement of the problem

Now a days there are different local garages and industries in Ethiopia that produce a different cargo bodies and trailers and which is a core business as a country. However, there are limited researches that study on this sectors which can be a bench mark for cargo bodies and trailer manufacturing companies. Because of this still those sectors are working in inefficient way. But those sectors need to support by scientific research out comes and needs to use a modified way of working and method to improve their operational performance.

The case company has a very low manufacturing (operational) performance when compared with the designed capacity of the facility.

Table 1.1. The actual performance and the design capacity of metal manufacturing factory and also the percentage (%) actual efficiency vs. design capacity Source: - KAKI PLC annual performance report and design capacity report

S/N	Fiscal year	Annual design capacity of the metal manufacturing factory with different product mix (units of product)	Actual annual metal manufacturing factory output with different product mix (units of product)	Percentage of workshop efficiency (actual performance vs design capacity)
1	2010 (2017/18)	740	131	17.7%
2	2011 (2018/19)		290	39.2%
3	2012 (2019/20)		111	15%
4	2013 (2020/21)		374	50.5%
5	2014 (2021/22)		164	22.2%

Table 1.2. Annual vehicle sales vs production output source annual sales report of the case company.

S/N	Fiscal year	Annual vehicle sales of Isuzu truck, Sino truck and Trailer (units)	Annual production output of different cargo body mounted on Isuzu vehicle, Sino truck and trailer	Percentage of production output vs annual sales
1	2010 (2017/18)	702	131	18.6%
2	2011 (2018/19)	871	290	33.3%
3	2012 (2019/20)	619	111	17.9%
4	2013 (2020/21)	665	374	56.2%
5	2014 (2021/22)	678	164	24.2%

As can see from Table 1.1, the last five years the annual performance (efficiency) of KAKI PLC metal manufacturing factory was averagely 28.92% per year and this was very low. Among these five years 2013(2020/21) is the one which had 374 products per year. But, 160 units of products were done by subcontracting which is outside the factory. When subtracted that 160 units the annual performance of the 2013(2020/21) became 28.9% and the average performance of five years became 24.6%. On the other hand, when the company outsourcing those 160 units the company costs 500 birr per unit product and total cost of 80,000 birr which is extra cost of the company because of low performance of the metal manufacturing factory. As shown from table 1.2, it showed the annual sales vs annual production percentage as of the report indicates the metal manufacturing averagely performs only 30% of the annual sales volume that means metal manufacturing factory not capable of fabricating about 70% of the annual vehicle sales and when it converts in to a revenue it is a lot.

Generally, this quantitative data indicates that the case company had very low performance and resource utilization like: -

- Poor space and facility utilization
- Poor machine utilization.
- Poor material utilization etc.

Annex A shows that the complaint letter from sales department to production department regarding the delivery date extension bend the promise date. This indicated that the company was exposed to a massive and continuous delivery date complaint from the customer this indicates that the lead time of the product is very high and exceed from the expected delivery date. Customer satisfaction means a lot for a company for sustainable growth but, as can see from annex A customer dissatisfaction is observed especially by delivery date of the product and if things are going in such a way without any change the company will be under risk because the business will dominate by competitors. This paper is works at assessing the root causes for the low performance of manufacturing factory and developing solutions for enhancing the poor performance of the case company.

1.3. Research question

Following the problem above, this research was expected to answer the following question:

1. What were the performance measures for cargo body and trailer manufacturing company?
2. What was the possible reason for low operational performance of the case company?
3. How could the operational performance of the case company was improved?

1.4. Objective the research

1.4.1. General objective

The general objective was to assess, evaluate and enhance operational performance of metal fabrication factory for cargo body, van body and trailer fabrication through lean practices.

1.4.2. Specific objective

- To identify appropriate operational performance measure for cargo body and trailer manufacturing workshop
- To assess and evaluate the root causes of low operational performance of manufacturing factory using appropriate lean tools like value stream mapping.
- To develop solution to enhance the operational performance of the manufacturing factory of case company using appropriate lean tools. Like:- value stream mapping and systematic layout planning
- To verify and validate the result by simulation using arena.

1.5. Scope of the research

The scope of the study was limited to assessing and evaluating the root cause for low operational performance of the case company using appropriate lean tool. During the research the data was gathered from different cargo body and trailer manufacturing factory like: Na metal fabrication, ANTA metal fabrication, Mesfin Engineering. By identifying the root cause this research was come with appropriate solution that gives the minimum production lead time, non-value adding activities and minimum wastes through lean practices. This research was not including all small cargo body fabrication garages. Basically the research is work to enhance the operational performance but not emphasize on quality assurance for the products.

1.6. Significance of the research

The outcome of this research is important for KAKIPLC especially for metal manufacturing business and also other manufacturing companies. By assessing and evaluating their manufacturing performance identify the cause for low efficiency and high production lead time. Once identifying the root cause for high production lead time and low efficiency this paper is working for develop a solution that gives minimum production lead time, minimum non-value adding activities and minimum wastes. By doing this the efficiency of the case company and other manufacturing that has related business with the case company become improved. Generally, this paper helps the case company to have maximum output with minimum cost.

1.7. Limitation of the research

During the research work there were several constraints faced especially during data collection data collection were made stop watch. But, the production process was not consistent.so, it needs more time to have complete data of one product production process end to end. The other constraint was some companies were not willing to show their production process during visit. Shortage of time also another constraint during the research work.

1.8. Motivational statements

The motivational factor that initiates to do this research first there was an observation of low operational performance of the case company and these phenomena initiated to do the research and develop the solution for the case company that can improve the efficiency and minimize the cost of the case company. In addition to this as can see from annex A there a letter about delivery date complains from sales department to fabrication. The letter indicates that there was a customer complain because of delivery date this means the lead time the product is beyond the expected. This phenomenon also initiated to do the research on assessment and evaluation and enhancement of the operational performance or productivity of the company.

1.9. Organization of the research

This research work was organized into six chapters. The first chapter was discuss about introduction including back ground and justification of the study, problem statement, objective, motivation, scope and limitation of the research. Chapter two was discuss about literature reviews about productivity, operational performance measures, lean production, industrial wastes, facility layout design using lean practice and research gaps. Chapter three discuss about methods and methodology of the study. Chapter four discuss about the back ground of the case company, key performance indicator of the manufacturing factories, the detail evaluation of the fabrication process of the case company based on selected products by using various models. Chapter five discuss about development of solution, validation and result and discussion. Finally chapter six discuss about conclusion, recommendation and future study area.

Chapter two

2. Literature review

2.1. Industry performance

Nwosu M.C. & Uzorh A.C. (2013) presented that performance is an achievement or output rate over a certain work or activity of a person in absence of delay factors. Operator performance is expressed as the ratio between total standard times for all measured and estimated work done and the time actually spent on that work. The total standard times produced by an operator are a direct function of the number of parts, pieces, amount of weight, volume, etc, produced and the standard times to produce them. Therefore, the total standard times for all measured and estimated work done equal the number of units of work produced.

$$opr ator\ performance = \frac{total\ standard\ minutes\ allocatted*100}{no\ of\ minutes\ to\ produce\ them} \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

$$operator\ performance = \frac{total\ weight\ produced*100}{total\ standard\ weight\ to\ consume} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Damtew et al. (2017) presented that due to the dynamic nature of manufacturing industries and with dynamic environment, the performance of organizations is changed drastically. But the main thing is what, how to measure performance and when to implemented performance measurements in organizations are the critical concepts that needs to addressed. Since, performance is the ability to meet certain criteria's, the time it takes, and the path used to get there. Also, performance is about how successful a business is in generating and sustaining value. Adane (2018) studied a manufacturing system embraces all procedures and facilities to transform raw materials into final products. Manufacturing system is a part of a production system, It is a complex arrangement of integrated equipment i.e., physical elements characterized or controlled by measurable system parameters and human resources, whose function is to perform one or more processing and/or assembly operations. The physical elements include machines, cutting tools, material handling, fixtures, etc.; the measurable parameters are production rate, takt time (cycle time), total production time, capacity, unit cost, etc. The human resources are direct labor and indirect labor (including maintenance and repair personnel.

2.1.1. Factor that affects the performance of manufacturing system

There are numerous factors that are responsible the performance of manufacturing processes. Nwosu M.C. & Uzorh A.C. (2013) described power / energy, maintenance, training, safety, equipment and technology affect the performance of manufacturing workers in industry. Adem (2020) studied factor that affects the performance of manufacturing industries. These are: -

Human factors: Human skills such as work experience, training, and educational background.

Technology: New technology improves the productivity of the company.

Product Factor: Different product meets output requirement and judged by its customer demand.

Plant and equipment: The increased accessibility of the plant through proper preservation and reduction of idle time increases productivity.

Management style: Active and flexible management style is a better approach to increase productivity.

Material and Energy: Good quality material and low energy consumption materials will improve productivity.

Work methods: Proper work method improves productivity, work-study and industrial engineering techniques and training are the areas which improve the work methods.

2.1.2. Methods used to measure the performance of the manufacturing system

Kibira et al. (2016) said maintaining high performance for today's manufacturing systems requires employing methods and tools to manage performance throughout the system life cycle. During system design, for example, methods and tools model, analyze, and test the system so that anticipated manufacturing needs and operating environments are investigated before the system is built. In the operation of the system, methods and tools are employed to ensure that the system maintains planned performance through monitoring, assessing performance, and responding appropriately to performance deviations. There are three categories of methods and tools used in manufacturing systems:

• Performance measurement
• Performance analysis
• Performance improvement

Performance measurement: - Performance measurement is the process of collecting, analyzing, and reporting performance information. The decision on what to measure stems from the objectives and policies of the organization. Measurements from the shop floor are analyzed and results are rolled to higher levels to determine system performance.

The most commonly used performance measurement frameworks according to Kibira et al. (2016) are:
• Balanced score card,
• Performance measurement matrix,
• Strategic measurement and reporting technique – SMART,
• Performance prism.

➢ Balanced Scorecard

Al-Adwan (2018) studied balanced scorecard (BSC) is one of the most widely used performance measurement systems, worldwide. BSC is a set of measures that gives top managers a fast but comprehensive view of the business. The balanced scorecard includes financial measures that tell the results of actions already taken. It complements the financial measures with operational measures on customer satisfaction, internal processes, and the organization's innovation and improvement activities – operational measures that are the drivers of future financial performance. Management processes and focuses the entire organization on implementing long-term strategy and a framework for managing the implementation for strategy'. Furthermore, they also believe that the balanced scorecard can only translate a company's strategy into specific measurable objectives. Balanced scorecard translates an organization's mission and strategy into a comprehensive set of performance measures that provides the framework for a strategic measurement and management system.

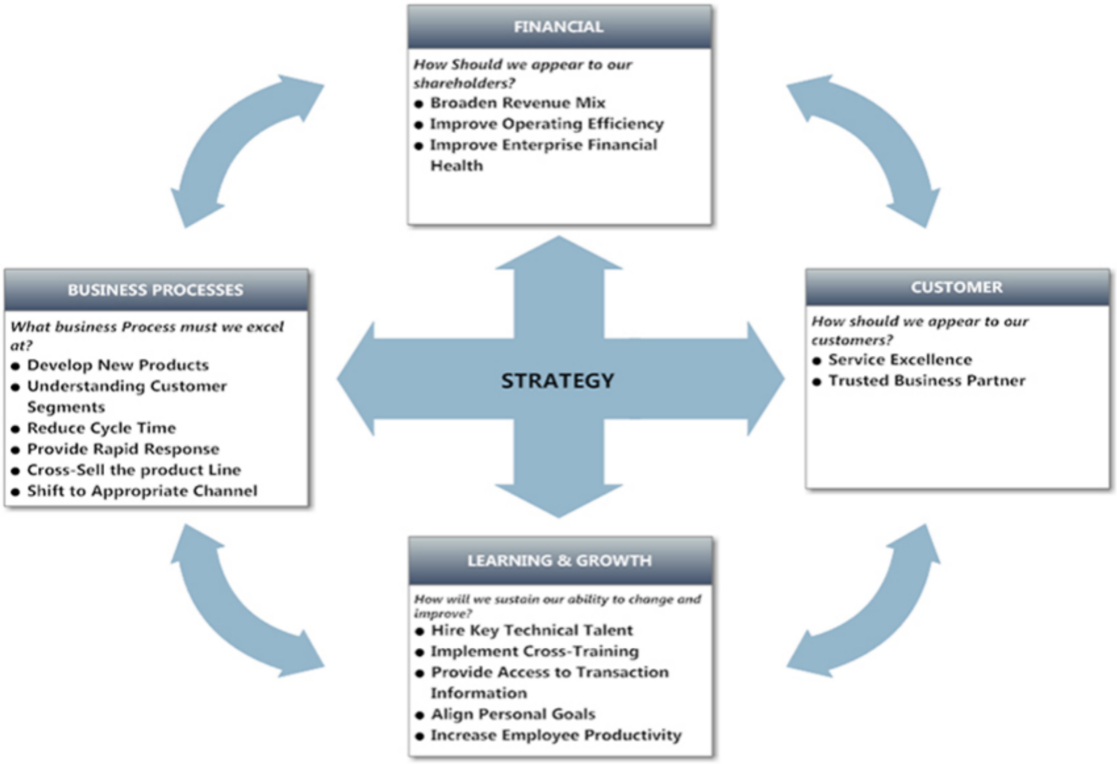

Figure 2.1. Balanced scorecard model (Al-Adwan (2018).

- **Performance measurement matrix**

Performance measurement matrix was developed to answer the need for balanced measurement. After realizing that many organizations have far too many irrelevant performance measures. It was felt that some of these measures were obsolete and inconsistent and that they could actually frustrate implementers of organizational strategy. The premise of the performance measurement matrix is that measures have to be classified into financial and non-financial impacts on business performance, each depending on both internal and external drivers. The system was modified and the modified measurement matrix assumes two basic types of performance measures, those relate to results (competitiveness, financial performance), and those focus on the determinants of the results (quality, flexibility, resource utilization, and innovation). The results are termed "lagging" while the determinants are "leading" indicators Kibira et al. (2016).

- **Strategic measurement and reporting technique -SMART**

Strategic measurement analysis and reporting technique (SMART) system was developed by Wang Laboratories, Inc. as a result of dissatisfaction with traditional performance measures such as utilization, efficiency, productivity and other financial variances. The objective was to devise a management control system with performance indicators designed to define and sustain success Khourshed (2015).

- **Performance prism**

Helia et al. (2021) said that Performance prism is a performance measurement system that is a refinement of the previous performance measurement system. The framework from performance prism is categorized into two aspects: business performance review and performance measurement review. Performance prism refers to the needs and desires of the stakeholders that must be considered first. Moreover, the balanced scorecard is more focused on financial results. It has not been able to determine the compensation system appropriately regarding the follow-up of the performance evaluation results. Performance prism also provides a comprehensive performance measurement by translating stakeholder satisfaction and contributions towards organizational goals, strategies, business processes, and capabilities.

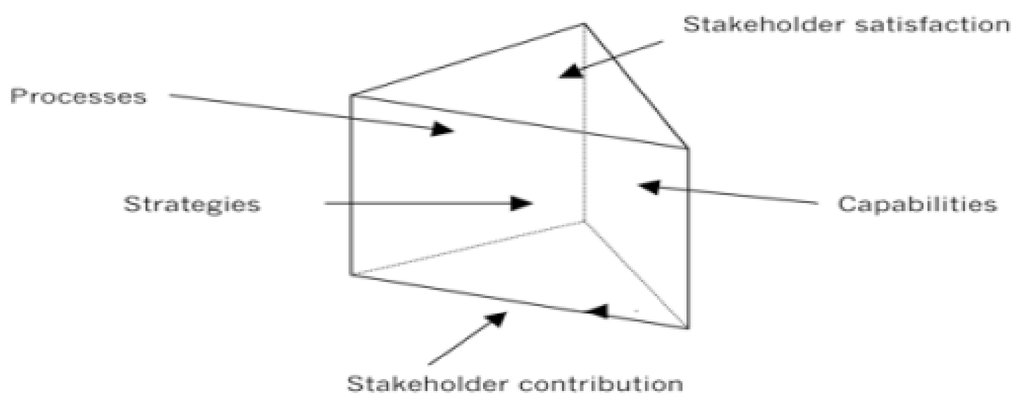

Figure 2.2. Performance prism scheme (Helia et al. (2021)).

2.1.3. Key performance indicator (KPI)

KPIs are defined as the quantifiable and strategic measurements that reflect enterprise's critical success factors. KPIs used to evaluate the performance of manufacturing production systems have been given more attention both in the academia and industry in recent years Johnsson et al. (2017).

- **A framework for organizing KPIs in the process industry**

A framework can provide useful ideas for manufacturing engineers and decision-makers aiming to define and measure suitable KPIs for performance evaluation in process industry. The framework will help structuring the KPIs and the associated measurement elements.

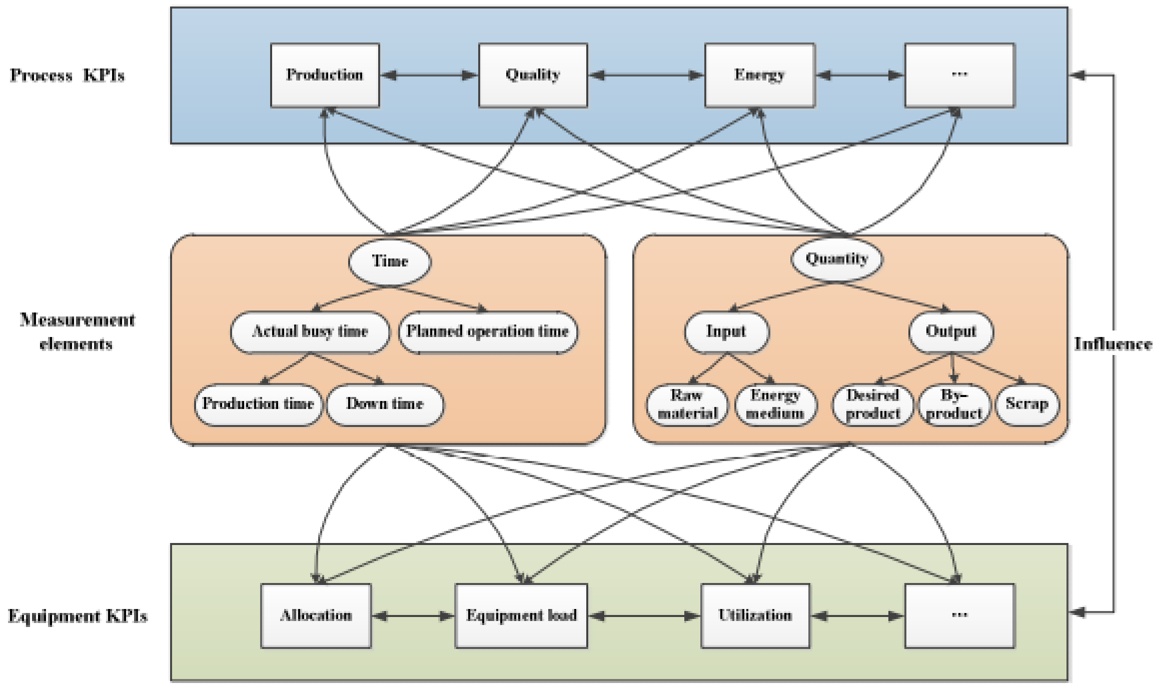

Figure 2.3. Framework for organizing KPIs in the process industry (Johnsson et al. (2017)).

Basic measurements called measurement elements have to be collected in order to calculate the KPIs. The measurement elements, middle part of the Framework in Figure 2.3, are comprised of the data directly monitored and collected during the production process. These are used to describe and calculate the equipment KPIs and process KPIs. Below the list of the basic measurement elements according to characteristics of the process industry company is provided.

Time elements

Planned operation time (POT): the scheduled time during which the equipment or process can be utilized Johnsson et al. (2017). Actual busy time (ABT): the actual time for execution and production. Actual production time (APT): the actual time in which the equipment or process is producing. Actual down time (ADT): the time in which the equipment or process is delayed due to malfunction caused interruptions, minor stoppages and other unplanned events Johnsson et al. (2017).

$$ABT = APT + ADT \qquad (4)$$

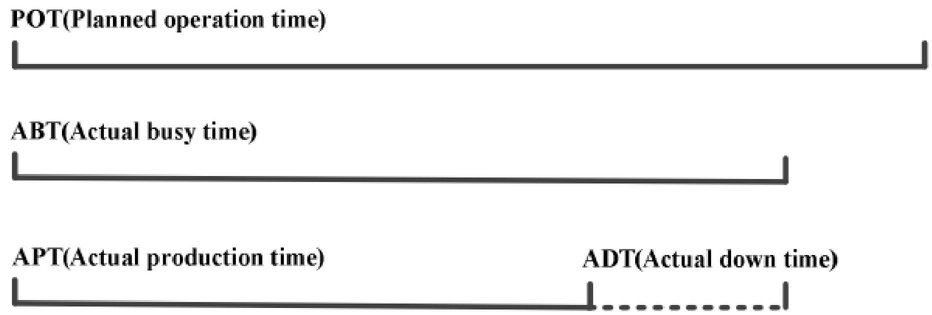

Figure 2.4. Relationship among the time elements (Johnsson et al. (2017)).

Quantity elements

Input quantity (IQ): the material used for equipment or process to produce the output. Raw material quantity (RMQ): the feedstock used to produce the output. Energy medium quantity (EMQ): the energy material used to provide the necessary energy for production Johnsson et al. (2017). Output quantity (OQ): the items that satisfy the requirements of production, including products and energy. It should be noted that the commonly used term in industry is produced quantity. Desired product quantity (DPQ): the primary product, which the production process is originally designed for. By-product quantity (BPQ): the secondary product generated during the production of the primary product. Scrap quantity (SQ): The result of the production process which cannot be transformed in product, including waste materials.

$$IQ = \{RMQ, EMQ\} \qquad (5)$$

$$OQ = \{DPQ, BPQ, SQ\} \qquad (6)$$

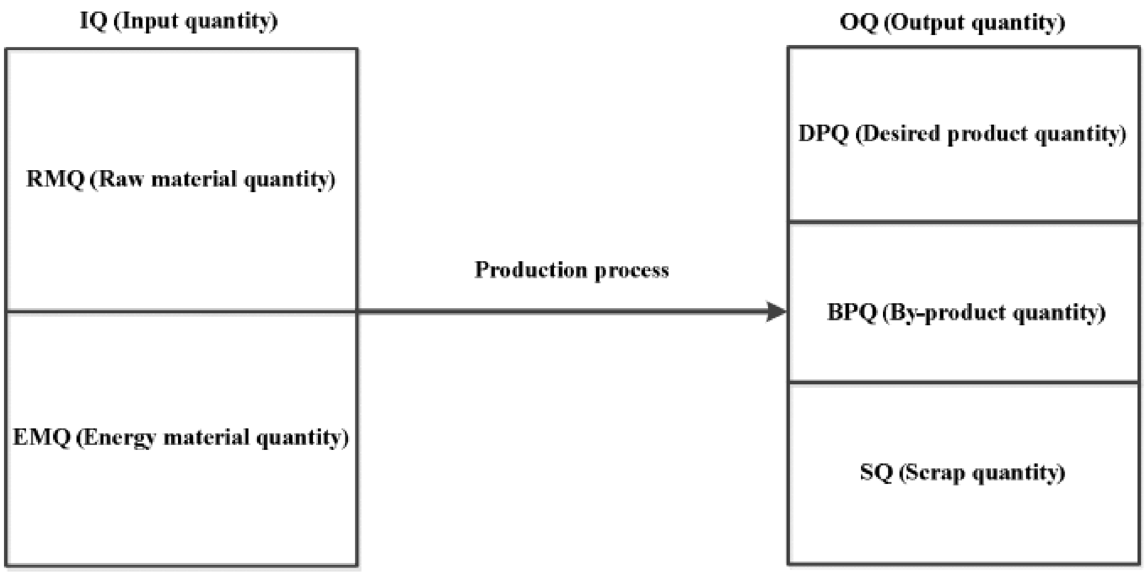

Figure 2.5. Relationship among the quantity elements (Johnsson et al. (2017)).

➢ Equipment KPIs

The equipment KPIs, lower part of the Framework are calculated based on the measurement elements.

Allocation ratio (AR): the percentage of actual production rate and maximum production rate. It provides the valuable information on the allocation of available capacity (Johnsson et al. (2017)).

$$AR = \frac{(Actual\ OQ)/_{ABT}}{(maximum\ OQ)/_{APT}} \quad \text{(7)}$$

Utilization efficiency (UE): the ratio between actual production rate and planned production rate.

$$UE = \frac{actualOQ/_{ABT}}{(planned\ OQ)/_{POT}} \quad \text{(8)}$$

Equipment load ratio (ELR): the ratio of actual produced quantity in relation the maximum equipment production capacity (EPC), which shows what the equipment parts actually produce when it is in progress to the load it could achieve.

$$ELR = \frac{Actual\ OQ}{(maximum\ PQ)/_{APT}} \quad \text{(9)}$$

Process KPIs

The process KPIs, upper part of the Framework are calculated based on the measurement elements.

Production process KPIs

Throughput rate: measures the produced quantity per order in relation to the actual busy time, and often used in the name of production rate (PR) in process industry.

$$PR = \frac{OQ}{ABT} \quad (10)$$

Technical efficiency (TE): the relationship between the production time and the busy time.

$$TE = \frac{APT}{ABT} \quad (11)$$

Quality process KPIs

Quality ratio (QR): the relationship between the desired product quantity and the produced quantity.

$$QR = \frac{DPQ}{OQ} \quad (12)$$

Actual to planned scrap ratio (APSR): the ratio relates the actual quantity of scrap to planned scrap quantity.

$$APSR = \frac{actual\ SQ}{planned\ SQ} \quad (13)$$

Scrap ratio (SR): the relationship between the scrap quantity and the produced quantity

$$SR = \frac{SQ}{OQ} \quad (14)$$

Finished goods ratio (FGR): the ratio of the desired product quantity produced in relation to the input material, including energy material quantity.

$$FGR = \frac{DPQ}{IQ} \quad (15)$$

Energy process KPIs

Energy consumption (EC): the ratio between all the energy consumed in a production cycle and produced quantity.

$$EC = \frac{EMQ}{OQ} \text{..(16)}$$

There are also other methods that are used to measure the performance the manufacturing company.one of these are measurement of the performance is performed by using the framework that incorporate the whole concept around the performance measurement as shown below.

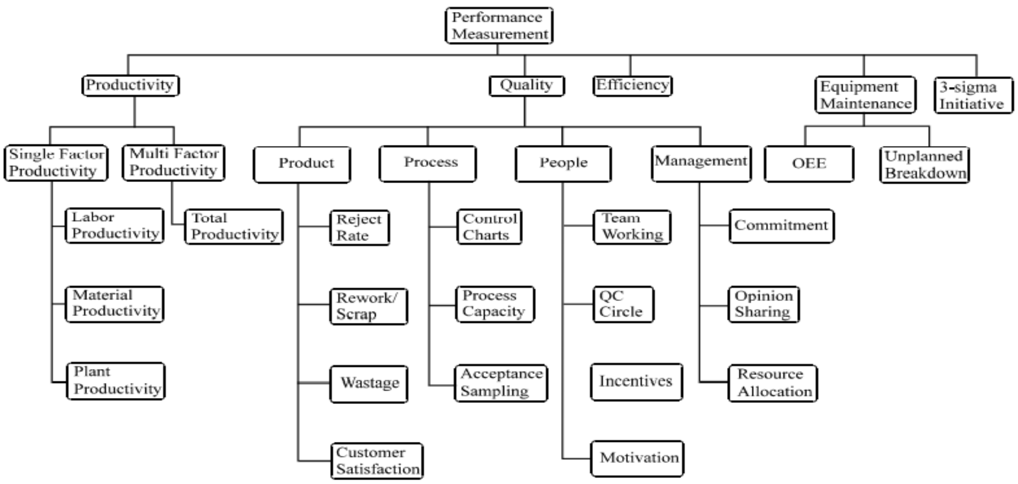

Figure 2.6. Performance measurement framework (Ahmed et al. (2014)).

2.1.4. Methods and tools used for performance improvement for manufacturing industry

Previously discussed about what performance is and what are the approaches used to measure the performance of the manufacturing sectors and now discuss about the tools and methods used for performance improvement.

Grunberg (2007) presented different number of methods however, the choice of improvement methods that actually analyzed were restricted. The studied methods are from the areas of Logistics, Quality, and Production Engineering and Behavioral area. For this paper, it is better to looking for production and engineering areas.

- **Production and Manufacturing**
  - Total Production Maintenance (TPM)
  - Lean Production
  - Demand Flow Technology (DFT)

- Read a plant fast
- Simulation
- Process mapping
- Single Minute Change of Die (SMED)
- Five S (Grunberg (2007).

The above listed methods are the methods that are used to improve the performance of the manufacturing industries. Among these various methods this paper is focus on lean production.

- **Lean Production**

Murugesan et al. (2016) said that Lean Manufacturing is a technique originally developed in the automotive industry that concentrates on shortening the time between the customer's order and shipment. Lean manufacturing has been applied very successfully in manufacturing operations, resulting in shorter production lead times, greatly reduced inventories, and significantly enhanced profitability. These techniques also promote improved flexibility, enhanced reliability and substantial cost reductions. This study addresses the implementation of lean tools in a job shop production system, with a focus on elimination of process bottle necks and elimination of manufacturing wastes. Value stream mapping (VSM) was the main tool used to identify the opportunities for various lean techniques. The effects of lean and value addition are clearly demonstrated by the VSM. A noticeable reduction in lead time and work-in-process inventory level is also achieved.

Gebeyehu et al. (2022) stated that lean system is concerned on minimizing wastes and enhancing production lead time so that it has been implemented in different manufacturing industries. For example, it is used to improve the process efficiency and productivity of metal production and a great deal of improvements have been achieved. The purpose of this paper is to use the lean principles, practice and tools in Hibret Manufacturing & Machine Building Industries (HMMBI) in Ethiopia. The study aims to improve the production lead time by minimizing non-value adding activities associated with several resources in the process. The process time and floor layout are studied and mapped using Value Stream Mapping, and Spaghetti Diagram to identify wastes. The result shows that production lead time, work in process (WIP), non-value adding time (waiting time) and total distance traveled are reduced. Zikre S. S (2019) presented that Industry's main motive is giving a product/service with the full satisfaction to clients by reducing the wastes, improve the productivity, to train the people and create a quality-oriented mindset. Lean Manufacturing tools and techniques are widely used in the most of the companies and exported all over the world. Lean manufacturing is all about removing waste from process by means of transportation, inventory, motion, weighting, over processes, over production and defects. In this study the case company demanded a new plant layout for the better material movement to improve the actual productivity by eradicating all the wastes in the process with the help of lean tools. Authors prepared a new layout based on the present scenario from random layout to U shape layout by utilizing cellular manufacturing to minimize the travel distance of both employees and material. Tools like 5W1H, Value Stream Mapping (VSM), Cause and Effect Diagram and 5Why are used to find the root cause of the current obstacles. And Kaizen tool was used with Pareto chart to identify the primary reason for the problem.

Wickramasinghe. (2017) studied lean production centers on the elimination of waste and creation of value. Waste in the context of lean production includes all that does not add value to the product or service from the customer’s perspective. Hence, waste is diverse including overproduction, waiting times, unnecessary movement of materials, inappropriate processing, inventory, defects, underutilization of people, environmental waste, and underutilization of facilities. Value added activities include activities perceived as being important by the customer and those are performed correctly the first time. The purpose of the study is to investigate the effects of lean production practices and lean duration (the duration for which lean production is in operation) on manufacturing performance. Design/methodology/approach- The survey was used as the main method of data collection is survey. The findings revealed that lean production practices significantly enhance manufacturing performance. Further findings revealed the importance of the duration of lean production in operation in achieving higher levels of manufacturing performance.

Haider, A. and Mirza, J. (2015) conducted a research on an implementation of lean scheduling in a job shop environment. A manufacturing industry was selected that was rebuilding battlefield tanks. The existing system was suffering delays and missing delivery targets due to uncertain and costly production. The proposed and existing systems were modeled and simulated using Arena

10.0 software. This work was successful in reducing the manufacturing-led time, work in process inventory and average cycle times with a reduction in cost and space utilization.

- **Industrial Wastes**

Singh et al. (2014) stated that there are seven main types of wastes were identified as a part of the Toyota Production System. However, this list has been modified and expanded by various practitioners of lean manufacturing and generally includes the following:

1. Overproduction: overproduction is unnecessarily producing more than demanded, or producing it too early before it is needed. This increases the risk of obsolescence, increases the risk of producing the wrong thing and increases the possibility of having to sell those items at a discount or discard them as scrap. However, there are some cases when extra supplies of semi-finished or finished products are intentionally maintained, even by lean manufacturers.

2. Defects: In addition to physical defects which directly add to the costs of goods sold, this may include errors in paperwork, provision of incorrect information about the product, late delivery, production to incorrect specifications, use of too much raw materials or generation of unnecessary scrap.

3. Inventory: Inventory waste means having unnecessarily high levels of raw materials, works-in-process and finished products. Extra inventory leads to higher inventory financing costs, higher storage costs and higher defect rates. Inventory tends to increase lead time, prevents rapid identification of problems and increase space requirements, thereby discouraging communication. **4. Transportation:** Transportation includes any movement of materials that does not add any value to the product, such as moving materials between workstations. The idea is that transportation of materials between productions stages should aim for the ideal that the output of one process is immediately used as the input for the next process. Transportation between processing stages results in prolonging production cycle times, the inefficient use of Labour and space and can also be a source of minor production stoppages.

5. Waiting: Waiting is idle time for workers or machines due to bottlenecks or inefficient production flow on the factory floor. Waiting also includes small delays between processing of units. Waiting results in a significant cost insofar as it increases labor costs and depreciation costs per unit of output.

6. Motion: Motion includes any unnecessary physical motions or walking by workers which divert them from actual processing work.

7. Over-processing: Over-processing is unintentionally doing more processing work than the customer requires in terms of product quality or features- such as polishing or applying finishing in some areas of product that will not be seen by the customer.

These wastes are a loss for a manufacturing company and the concerning group need to focus on these things and should have eliminate those wastes.

Figure 2.7. Seven wastes (Fransson (2020)).

- **Lean Management Techniques**

Wondwossen (2020) presented that lean management techniques are based on the application of five principles to guide management action toward success. These five principles are the following:

1. **Value:** Define value for a specific product from the customer perspective which meets customer needs.
2. **The value stream**: Identify all the steps in a value stream across all parts of the organization involved jointly delivering a product to the customer. Identifying the value stream exposes as non-value adding process steps

3. **Flow:** Make the value-creating step flow in tight sequence so that the production flows smoothly towards delivering products to the customer without wastes such as waiting & interruptions.
4. **Pull**: Produce only what the customer wants when the customer wants it.
5. **Perfection:** Having value specified, value stream identifies, waste removed, flow and pull introduced the process should be in continuous improvement until the state of perfection is reached in which every action adds value for the end customer (Zero waste).

By using these techniques manufacturing companies are expected to enhance the productivity performance and reduce any wastes.

2.1.5. Facility lay out design through lean practice

Lista et al. (2021) conducted lean layout design: a case study applied to the textile industry. To showcase the application of LM (lean manufacturing) on plant layout design. Information is collected through multiple site visits and semi-structured interviews with the company's key staff, as well as examination of relevant company documentations. Layout planning and development might be considered time-consuming and a difficult task. However, some techniques are generally used to plan layout designs like Value Stream Mapping (VSM), product family identification, activity relationship chart, and block diagram. These techniques are the very important and helpful techniques to implement SLP (systematic layout planning).

VSM can be understood as a visual representation of all value and non-value-added activities to manufacture a product with its materials and information flows. Through the current value flow map, it is possible to follow a product's production path as they occur, from supplier to customer, and then generate another flow chart to illustrate a possible future situation with greater performance. When constructing VSM product family identification and activity relationship chart are important.

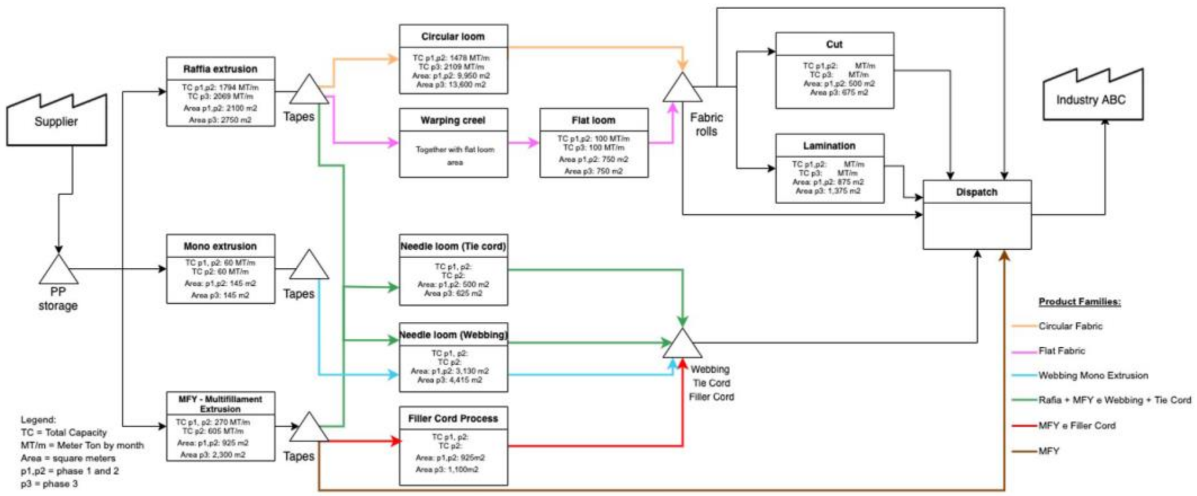

Figure 2.8. Current VSM of all product families (Lista et al. (2021)).

Product family identification: - It is a tool to gather a group of products with similar processing steps and work contents.

Activity relationship chart: - It is an indicator of the degree of distance between pairs of activities. The activity relationship diagram is also called the affinity analysis diagram, and it shows the relationship of every department, office, or service area with every other department. It helps to organize activities that need to be close to each other in the relevance of importance by displaying the closeness rating between them.

Ahmad et al. (2019) studied on layout improvement towards lean system in manufacturing company. The authors used as method of interviewing, data collection and observation. Layout design and the flow of materials is significantly affected the performance of manufacturing. These can help to reduce work in process and inventory, increase productivity, reduce streamlines the flow of materials, reduce production lead time, and reduce non-value-added activities from the production process of waiting and movement, ultimately fulfill the customers' requirement. Basically, there are three main concepts of layouts, namely product layout, process layout, and fixed position layout and the studied company used product layout. So, in order to design different lay-out there are different concepts which the author used like. Centralized location, material handling, and smooth movement and space utilization.

Tarigan et al. (2019) conducted a case study on Facility Layout Design through Integration of Lean Manufacturing Method and CORELAP Algorithm in Concrete Factory.

CORELAP (Computerized Relationship Layout Planning) algorithm uses the proximity relationship rating stated in Total Closing Rating (TCR) in selecting workstation placement. A department's TCR is the number of values of the department's relationship/closeness to other departments. Analysis and data processing is performed by using the following steps

- Value Stream Manager
- SIPOC (supplier, input, process, output, customer) Diagram
- Standard Time Calculation
- waste Identification
- Map Creation for Each Process Category Throughout the Value Stream
- Overall Factory Process Chart
- Process Cycle Efficiency Calculation
- Process Added Mapping Analysis

The improvement using lean manufacturing is by using the following steps

- Initial Layout
- Distance Calculation
- Transportation Frequency Calculation
- Moment of Displacement
- Alternative Layout construction using CORELAP Algorithm
- Proposed Process Activity Mapping
- Future State Map

The CORELAP algorithm calculation uses the proximity relationship expressed with Total Closeness Rating (TCR) as the basis for calculating the selection of workstation placement. The principle of CORELAP Algorithm analysis is to determine the largest layout score, which shows that the relationship between departments is better. This TCR calculation is based on qualitative data of Activity Relationship Chart. The Activity Relationship Chart data is then converted into numerical form with a base rating of TCR values.

Table 2.1. Base rating of TCR value (Tarigan et al. (2019)).

Code	TCR value
A: Absolutely must be nearby	5
E: Very important to be nearvy	4
I: Important	3
O: Does not matter	2
U: No need to be near by	1
X: Not expected to be nearby	0

Zikre S.S (2019) conducted a case study on design of new plant layout using lean tools by eliminating wastes in material flow process a case of aerospace parts manufacturing industry located in Windsor, Ontario. As a tool the author uses like 5W1H, Value Stream Mapping (VSM), Cause and Effect Diagram and 5Why are used to find the root cause of the current obstacles. And Kaizen tool was used with Pareto chart to identify the primary reason for the problem.

VSM includes all activities from the customer demand to transform a product from raw material into the finished product. The VSM is drawn for every process involved in the material and information flow. Thus, by creating a process flow we can identify the value-added and non-value-added activities involved in the process. The VSM consists of current and future state mapping. The current state is used to describe how the process is being done and by identifying the problem.

During root cause analysis Zikre (2019) presented that there is a famous saying in a book called Toyota Way by Jeffrey K Liker which is “See America, Then Design for America”. To follow this saying, followed 5G and 5W1H to understand the real problem in the company. Table 02 shows information regarding root cause analysis. At first, have done a Gemba walk throughout the shop floor to understand the problem. Because, it is the most powerful location for any team. 5W1H is the important tool to understand the problem more deeply.

Table 2.2. 5W1H diagram (Zikre (2019)).

What is the problem?	Excessive movement of material and man
When is it occurring?	All the time during production
Where is it occurring?	CNC to inspection: packing to dispatch
Who is doing it?	Material handler
Which pattern does it have?	Twice in a day. (30 minutes/each)
How it is being done?	Changing the layout

Cause and effect diagram

Potential probable causes of the problem have to be identified. A cause-and-effect diagram can help in brainstorming to find possible causes of the problem which may be more. The problem is shown at the head of the fish. Possible causes are displayed through brainstorming on the smaller bones under different categories like Man, Machine and Material.

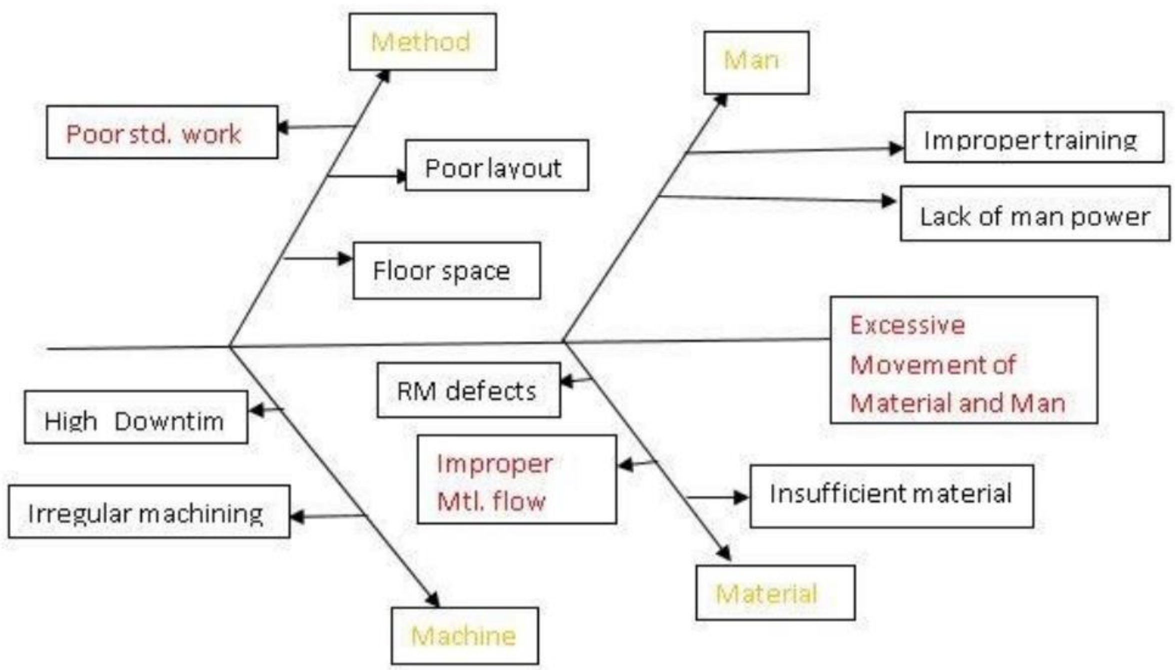

Figure 2.9. Cause and effect diagram (Zikre (2019)).

Root cause of the problem can be found out using 5Why Analysis which is one of the oldest methods in finding the root cause.

Aswin (2018) studied the lean implementation using root cause analysis approach in machine tool industry. As stated from this paper root cause analysis is a structured investigation that aims to identify the true cause of a problem and the actions necessary to eliminate it. As a method from this paper identification of the major problems among all the problems is by pareto analysis, finding the root causes of major problems using cause and effect diagram.

Murugesan et al. (2016) conducted a case study conducted at job shop production facility that produce a brake piston. By using value stream mapping the previous manufacturing process can visualize and identify the problem which is spending a large cycle time during manufacturing process. And the reason for this large cycle time was having poor production layout which has different non-value adding activities. So, standing from the existing state of map of the process they redesign the layout which have a better improvement.

Gebeyehu et al. (2022) conducted a case study on Hibret Manufacturing and Machine Building Industry (HMMBI) to improve the production lead time. Both qualitative and quantitative data collection techniques are used in the case study. The existing layout of the work station is drawn using value stream map. The movement of the materials and workers is also shown using spaghetti model. Using the techniques Sigma XL helped to analyze the future value stream map for value adding, non- value adding and necessary non-value adding activities whereas Quality Companion is used to calculate lead time, WIP time, takt time, cycle time, value adding cycle time, non-value adding cycle time and total travel distances. For reducing the production lead time: process efficiency, cycle time, production rate, machine uptime and over all equipment effectiveness are taken into account as key performance indicators. Finally, this paper identified a set of critical issues affecting the production lead time of the case study which is poor production layout by integrating lean manufacturing system and manufacturing performance indicators.

Sobhi (2018) studied on the impact of implementing the lean production tools in a candy food Industries Company. Value stream mapping was used to study the current state of the production line and focuses on the major defects rate and also identify the main kind of waste in the production line. This paper is focusing on collecting qualitative data about the major kinds of waste in the production line, and analyzing those data to find the root causes of the major wastes in all processes in the production line by using a cause-and-effect diagram.

Table 2.3. Summary of literature review.

Authors name	tittle	objective	method	finding	Gap/limitation
Ana Paula Lista. Et al. (2021)	Lean layout design: a case study applied to the textile industry	To propose a new facility layout for an Indian textile company based on guidelines for Systematic Layout Planning (SLP) and Lean Manufacturing (LM).	The application of LM on plant layout design. And Information is collected through multiple site visits and semi-structured interviews with the company's key staff, as well as examination of relevant company documentations.	Develop a new model that leads to costs reduction handling and unnecessary movements reduction	The study focus on only the case company layout design. And have no experimental validation.
U Tarigan. Et al. (2019)	Facility Layout Design Through Integration of Lean Manufacturing Method and CORELAP Algorithm in Concrete Factory	To obtain the layout design of concrete plant facilities through simplification of the production process to increase the company's production capacity.	By using integrate lean manufacturing methods and CORELAP algorithms.	Obtained process cycle efficiency improvements on the results of the lean manufacturing method approach and increased production capacity per day.	The result is not experimentally validated.

Aswin and Vinod (2018)	`	To implement lean manufacturing in the production of central lathe in a machine tool company.	By using root causes analysis and cause and effect diagram	reduces the wastages in production of process	The implementation is not gone as the author intended
Sriram Srinivasan and Harita Zikre (2019)	Design of New Plant Layout Using Lean Tools by Eliminating Wastes in Material Flow Process	To prepared a new layout based on the present scenario from random layout to U shape layout	By using 5W1H, Value Stream Mapping (VSM), Cause and Effect Diagram and 5Why.	Develop new lay out and expected to have better productivity	The result is not experimentally validated
V. M. MURUGESAN, (2016)	manufacturing process improvement using lean tools	To addresses the implementation of lean tools in a job shop production system	By using Value stream mapping (VSM)	A noticeable reduction in lead time and work-in-process inventory level is also achieved.	The result is not experimentally validated
Sisay G. Gebeyehu, (2020)	Production lead time improvement through lean manufacturi	To improve the production lead time by minimizing non-value adding activities.	By using Value Stream Mapping, and Spaghetti Diagram to identify wastes.	Production lead time, work in process (WIP), non-value adding time (waiting time)	The problem is not clearly stated and the result is not

	ng			and total distance traveled are reduced.	experimentally validated

2.2. Research gaps

To gate enough information and best understanding about the field of study various kinds of literature from different sources like: - journals, reports, conferences and books are referred. Even though there are so many research works on performance improvement through lean production. There is limited research work focusing on the cargo body and trailer fabrication industries but it is a very essential manufacturing sector. In Ethiopia including the case company there are many cargos body and trailer fabrication industry. But there is limited research to support these industries. This paper is focus on enhancing the performance of these sectors by using lean practice.

Chapter Three

3. Research Methods & Materials

3.1. Study area

This paper is a real case study in the metal fabrication industry. The company is known as KAKI PLC which is located in Addis Ababa around sebeta (alemgena). This company has different products like: - cargo bodies, vans and trailers. It is equipped with different machines like: - welding machine, overhead crane, cutting and bending machine, forklift, and other tools and equipment. This paper is working for assessing the root causes for the low operational performance of this manufacturing factory and developing solutions for enhancing the poor performance of the factory.

3.2. Models used in this Research

3.2.1. Value Stream Mapping

Value Stream Mapping (VSM) is a tool which is used for analyzing the material flow, information flow necessary in delivering a product to the customer. The advantage of using this method allows anybody to "see" both process flow and communications flow within the process or value stream. The starting point for improvement process is knowing the current situation and places that has to be improved. To draw Value Stream Map, it is very important to use observational skills and document how the company looks & not to neglect or hide the exact situation Manjunath M.et al. (2014).

Value stream map is mainly divided into three sections:

- **Material flow:** - the team must identify the start and end points of the product, process description, material movements, and operator's details for drawing value stream.
- **Information or communication flow**: -Communication throughout the process must be proper and simple such that it can be understood by employees, suppliers, customers and management. Communication signifies informational flow between all the materials involved into the process and more than that into the entire company.

- **Time line**: - the time line represents the time needed for product to move through production process.

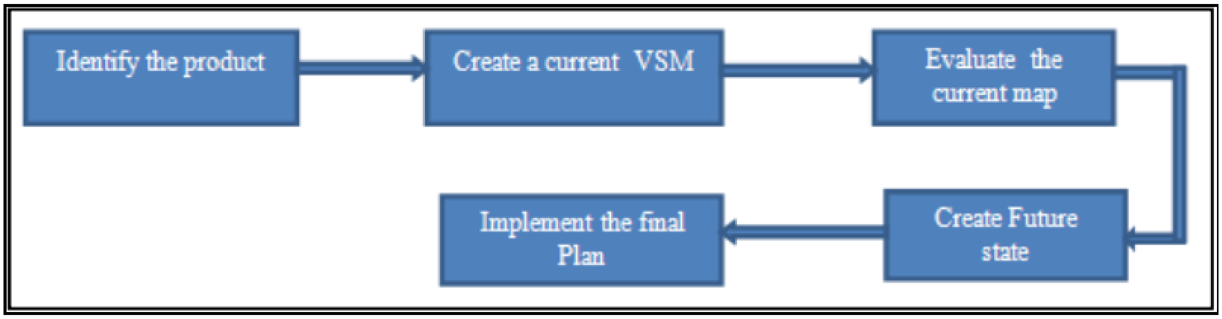

Figure 3.1. Steps involved in creation of VSM source Manjunath M.et al. (2014).

Current state of map

For drawing current state map the particular product process has to be observed, real time data is to be captured and it should be represented in pictures

Future state of map

After drawing the current state map, it is the time for team members to evaluate and list all the improvement actions required to draw the Future state. The Future State Map can be designed to monitor the positive changes that are required for the future Manjunath M.et al. (2014).

3.2.2. Systematic layout planning (SLP) model

To create an optimized plant layout design for case company this study is adopted the SLP model. The LM and SLP application in the layout design for the cargo body, van and trailer manufacturing facility consists of nine sequential stages as shown in Figure below:

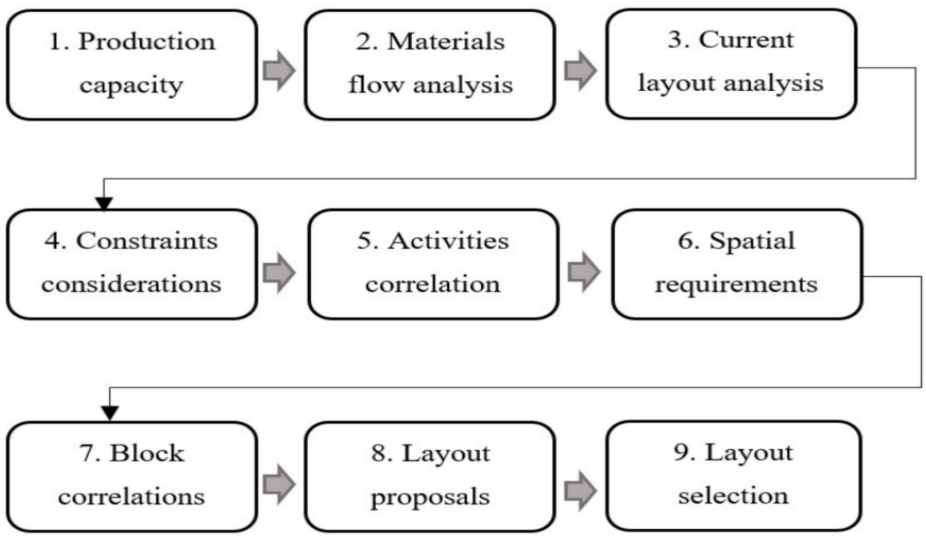

Figure 3.2. SLP model source Lista et al. (2021).

The first three stages of the SLP model refer to the study of the current situation of the company. More specifically, Stage 1 identified product families and evaluate the machine's capacity for the overall production activities. Stage 2 described the current flow of materials through a flow chart representation by using (VSM) value stream mapping. Stage 3 began with several factory visits to identify the current plant layout design and resource's allocations. The following three stages concern the identification of plant layout requirements and opportunities for improvements to guide further proposal's development. Stage 4 aimed to determine premises and restrictions regarding the plant layout design. In Stage 5 an activity relationship chart was created to help to find requisites considering the proximity level between departments. Stage 6 refers to the determination of space requirements so that every machine and storage area can be considered before planning layout proposals. After the above stages, it is possible to proceed with developing the final layout, firstly by creating a block correlation diagram (Stage 7), and then by proposing macro- and micro-layouts (Stage 8). Lastly, the final proposal was selected according to the company's criteria (Stage 9).

3.2.3. CORELAP Algorithm

Tarigan et al. (2019) presented that CORELAP (Computerized Relationship Layout Planning) algorithm calculation uses the proximity relationship expressed with Total Closeness Rating (TCR) as the basis for calculating the selection of workstation placement. The principle of

CORELAP Algorithm analysis is to determine the largest layout score, which shows that the relationship between departments is better. This TCR calculation is based on qualitative data of Activity Relationship Chart. The Activity Relationship Chart data is then converted into numerical form with a base rating of TCR values as shown in table 3.1 below.

Table 3.1. Base rating of TCR values Tarigan et al. (2019).

Code	TCR value
A: Absolutely must be nearby	5
E: Very important to be nearvy	4
I: Important	3
O: Does not matter	2
U: No need to be near by	1
X: Not expected to be nearby	0

Therefore, based on this algorithm first it is important to list out the activity involved in the production of an item. Then go for the TCR value by using different like practical observation, interview with operational managers, and interview with senior technician. Etc. and then go for layout arrangement accordingly.

3.3. Data collection

Data collection is the process of gathering and measuring information on variable interests. The purpose of data collection is to establish systematic fashion that enables one to answer a stated research question, hypothesis and evaluate out comes.

3.4. Source of data

Generally, sources of data categorize in to two primary data source and secondary data source as Ajayi (2017) studied Primary data refers to the first-hand data gathered by the researcher himself. Sources of primary data are, direct observations, stopwatch, and interviews. While secondary sources mean data collected by someone else earlier.

3.4.1. Data collection methods

Direct observation: - this is the very important way of data gathering by direct visit of the case company. During direct visit the necessary data will be gathered like: - technician movement, material handling, work station design, machine set up and process flow of the production department. For additional information beyond the case company other cargo body and trailer manufacturing companies are visit.

Stop watch: - Time study has been taken by stopwatch and using timesheet to determine the basic time for all operation sequences and to determine the lead time for each activity and finally can have the lead time for one product.

Interview: - from this study interview also conduct with production manager, production supervisor, senior technician, painter, satellite store keeper, quality controller, production planning and controlling manager and other to have relevant information during the study.

Literature review: - from this section different published journals, conferences, reports and books which has a relationship with this area of manufacturing industry performance enhancement by using lean practices are referred for having awareness about the field of study and gating information about the methods, model, tools and other supportive ideas for the study.

Document review: - in order to know about the existing problems and way of working it is essential to refer the company document like: - standard time of the product, starting and finishing date of the product, performance report and other related documents of the case company is referred.

Questioner: - prepared questioner based on causes for low operational performance of the case company. Structured questioners are prepared to getting a complete information for low operational performance of the case company. The questioner is directed to all stakeholders of metal cargo body and trailer fabrication process like: - production manager, production supervisor, technicians, engineering team, quality team, production planning and controlling team and satellite store keeper. Only full-time employee is used for participate in the questioner. The questioner is provided for 40 employees. And the nature of questioner is closed ended.

3.5. Data analysis

Data can be gathered from primary and secondary data source. These data need to be analyzed. During the analysis of the collected data from direct observation, stopwatch, interview, and relevant documents and the result of the data is present through bar chart, cause and effect diagram. Then the quantitative data that display by bar chart are analyze and interpret accordingly and describe qualitatively. Cause and effect diagram also use to find the root cause for the problem. the diagram is show the possible causes that are observed from the case company during direct sight observation.

The data that are collected from questioner are analyzed by using SPSS software version 20 which is very important for statistical data analysis. Mezgebe (2015).

3.6. Result validation

Finally, this paper develops a model that can enhance the performance of the case company. Doing an experimental validation of the manufacturing process is a time and budget consuming process. Therefore, the result validation is performed by using simulation software which is called arena. Arena is the best software that can show the whole necessary information of the manufacturing process.

3.7. Research design

Research design is the framework of research methods and techniques chosen by a researcher to conduct a study. The design allows researchers to sharpen the research methods suitable for the subject matter and set up the studies for success. The design composes all the procedures of the study from the beginning up to the end.

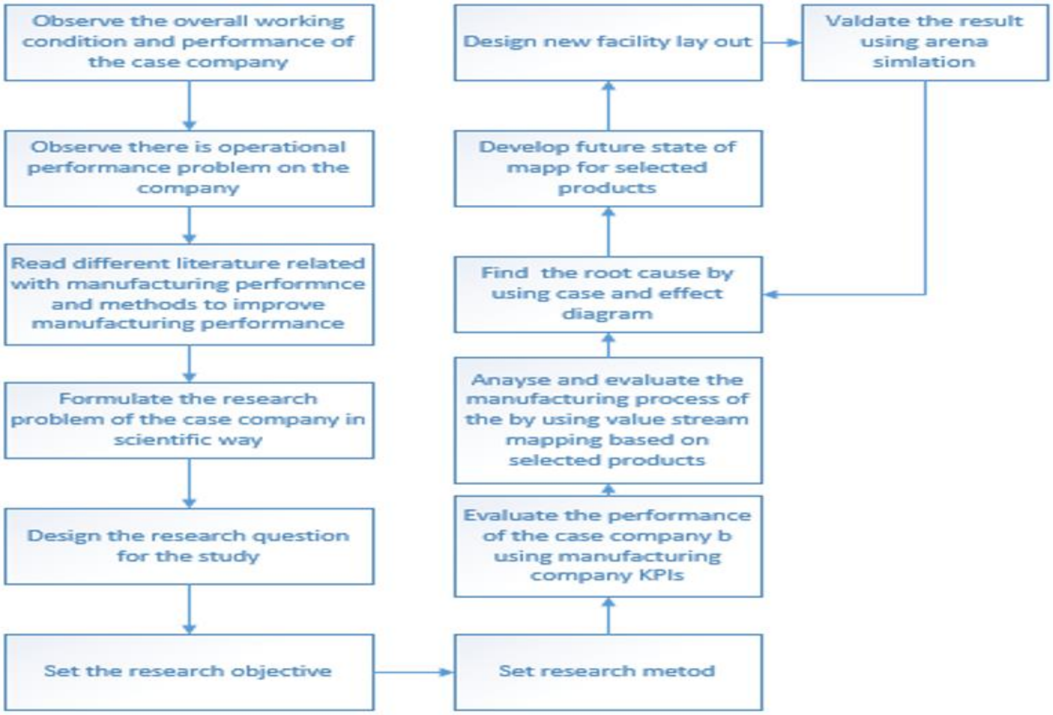

Figure 3.3. Research Design.

Chapter Four

4. Background & current performance analysis of the case company

KAKI PLC was incorporated as a plc in 2003 by Ethiopian family shareholders. Since its establishment the company has been making continuous growth and expansion by engaging in diversified business. Currently, KAKI is providing high quality products that are mainly tailored to import and export trading, manufacturing of dry land cargo bodies and parts, sesame, and cereal cleaning services, and dry Cargo transport services. The company has five business units (BU) including:

1. Vehicle Assembly & Metal Fabrication BU
2. Aftersales BU
3. Commercial BU
4. Export BU and
5. Freight Transport BU

Vehicle Assembly and Metal Fabrication Business unit is the one that are engaging with fabrication of different cargo body mounted on Isuzu tracks, Sino tracks, trailer and also Assembling of Isuzu NPR vehicles.

4.1. Performance measures of manufacturing factory

A manufacturing Key Performance Indicator (KPI) or metric is a well-defined and quantifiable measure that the manufacturing industry uses to gauge its performance over time. Manufacturing companies specifically use KPIs to monitor, analyze, and optimize operations, often comparing their efficiencies to those of competitors in the same sector. There are different KPIs used in manufacturing sectors.

1. Throughput (production volume) – This is one of the most fundamental KPIs for the manufacturing industry. The Throughput KPI measures the production capabilities of a machine, line, or plant; also known as how much they can produce over a specified time period.

Throughput = # of Units Produced / Time (hour or day)

2. Cycle Time –The cycle time metric can be used to measure the time it takes to manufacture a completed product, each individual component of the final product, or even go as far as to include delivery to the end user. Thus, cycle time can be used to analyze overall efficiency of a manufacturing process on the macro scale, as well as determine inefficiencies on a micro scale. Cycle time = Process End Time – Process Start Time

3. Takt Time – This is a very useful manufacturing KPI when scheduling production orders or deciding whether to take an order from a client. Takt time is the maximum permissible amount of time that can be spent manufacturing a product while still meeting a client's deadline.

Takt Time = Net Available Time / Customer's Daily Demand

4. Machine Downtime Rate – While this is commonly used as a manufacturing metric to give a general snapshot of how operation is going, it doesn't paint a full picture. Machine downtime is a combination of both scheduled downtime and unscheduled downtime.

Machine Downtime Rate = Downtime Hours / (Downtime Hours + Operational Hours)

5. Capacity Utilization – This production KPI measures the amount of capacity being utilized as a function of total capacity available. Ideally, companies want this number to be as high as possible, as it indicates they are making better use of their production capabilities and maximizing return on their assets.

Capacity Utilization = Actual Factory Utilization / Total Productive Capacity

6. First Pass Yield – This is one of the most fundamental productions KPIs. It calculates the percentage of products manufactured to specification the first time through the process. This means that they do not require any rework or become scrap. A higher FPY rate is very desirable for any company.

First Pass Yield Rate = Quality Units / Total Units Produced.

7. Manufacturing Cost per Unit – It is very important that you know the total cost associated with manufacturing a product on a per unit basis. This KPI takes into account all costs associated with production and divides the cost by the number of units manufactured. Typical costs include materials, overhead, depreciation, labor, etc.

Manufacturing Cost per Unit = Total Manufacturing Cost / # of Units Produced

8. On-Time Delivery – This is a very important KPI in the manufacturing sector. You can have the most efficient production line in the world, but if you can't deliver on time, clients are not going to want to work with you. This metric measures the percentage of products delivered on time to clients.

On-Time Delivery = (# Units Delivered On-Time * 100) / # Units Delivered

9. Scrap Rate – This is a fairly straightforward manufacturing KPI. It keeps track of the number of products that are deemed scrap due to manufacturing defects that can't be reworked. It gives companies insight into the ratio of products deemed scrap in a production run, helping identify an inefficient process.

Scrap Rate = # of Scrap Units / Total # of Units

4.2. Evaluating the performance of the case company by using manufacturing KPIs

By using manufacturing KPIs the performance of the case company is evaluated as follows. The case company has production planning and controlling (PPC) departments and it is part of the production system that coordinates and integrates the entire manufacturing activities in the production system. It plans, manages and controls job orders and the allocation of resources (human resource, raw material, and machinery) to achieve maximum efficiency.

PPC essentially comprises of planning production before actual production activities start and then exercising control over those activities to ensure that the planned production is realized in terms of efficiency, quality, and delivery schedule. The objectives of Production Planning and Control (PPC) is Plan and manage resources and capacities based on customer needs thus, enable the company to fulfil customer demand and ensure customer satisfaction and achieve other goals efficiently and with high quality.

Therefore, there is a monthly performance report from PPC department by using KPIs. For better evaluation it is better to use the last 6-month performance reports.

Performance parameters: - The acquisition of data related to the target process or system is crucial for the setup of the desired KPIs Process parameter data, such as system specifications, input variables, and process performance metrics, are needed for the analysis. The aforementioned indicators numerically describe the behavior of the resources, as well as activities performance. Despite a wide selection of performance metrics being presented in various literature, KPIs must be selected depending on the underlying strategies of the company. Golova et al. (2021). For the operational performance analysis and the objective of this study throughput, cycle time and on-time delivery are selected KPIs

1. Throughput: parameters used to evaluate throughput are number of unit produced and amount of time taken that express as follows: -

$Throughput$ = # of Units Produced / Time (hour or day) or

Throughput = $Average\ Inventory\ (I)\ /Average\ Flow\ Time\ (T)$ Golova et al. (2021).

2. Cycle time: cycle time is the amount of time that a product takes from the beginning up to the end. Parameters that are used to evaluate cycle time are process time and queue time which express as follows.

Cycle time = queue time + process time Li Zheng et al. (2009).

3. On-time delivery: on-time delivery is all about delivering the orders with an accurate promised date, not only on the available stock but also on procurement and distribution times of any raw materials from external sources.

Percentage of on-time delivery = # of units delivered on-time*100/ total # of units delivered Karim et al (2010).

Table 4.1. Monthly operational performance of the last 6-month of 2014 E.C fiscal year source monthly report of the company.

Performance achieved by the manufacturing factory for the last 6 month of 2014 fiscal year							
S/N	KPIs	March	April	May	June	July	August
		FSR cargo	FSR cargo	FSR cargo	FSR	FSR	FSR

		body=1.6 units	body=6.75units	body=1.74 units	cargo body=7 units	cargo body=10 units	cargo body=6.4 units
1	Throughput	FSR van=0	FSR van=0	FSR van=1 unit	FSR van=0	FSR van=0	FSR van=0
		FSR bus=0	FSR bus=0	FSR bus=0	FSR bus=0	FSR bus=0	FSR bus=0
		NPR cargo body=0	NPR cargo body=4 units	NPR cargo body=3 units	NPR cargo body=2 units	NPR cargo body=3 units	NPR cargo body=2 units
		NPR van=26.5 units	NPR van=9.62units	NPR van=3 units	NPR van=1 units	NPR van=2.35 units	NPR van=3 units
		NPR bus= 0.7 units	NPR bus =0.7 units	NPR bus= 0.2 units	NPR bus= 0.5 units	NPR bus=0.14 units	NPR bus =0
		Sino cargo body= 1.5 units	Sino cargo body= 0	Sino cargo body= 0	Sino cargo body=	Sino cargo body= 0	Sino cargo body= 0
		Trailer=3.15 units	Trailer=4.5 units	Trailer=1.35units	Trailer= 0	Trailer= 0	Trailer= 0
		Total= 33.45units	Total= 25.57units	Total= 10.29 units	Total= 10.5units	Total= 15.49 units	Total= 11.4 units
2	On-time Delivery	50%	44%	55%	50%	40%	53%

Table 4.2. Year to month plan that gives as a target for manufacturing factory for the last 6-month of 2014 fiscal year E.C source annual plan of the company.

Plan that gives as a target to manufacturing factory for the last 6 month of 2014fiscal year							
S/N	KPIs	March	April	May	June	July	August
1	Throughput	FSR product=12 units	FSR product=12 units	FSR product=14 units	FSR product=12 units	FSR product=11 units	FSR product=11 units
		NPR product=31 units	NPR product=44 units	NPR product=39 units	NPR product=39 units	NPR product=17 units	NPR product=24 units
		Sino product=6 units	Sino product=6 units	Sino product=7 units	Sino product=6 units	Sino product=1 units	Sino product=1 units
		Trailer=6 units	Trailer=6 units	Trailer=7 units	Trailer=6 units	Trailer=1 units	Trailer=1 units
		Total=55 units	Total=68 units	Total=55 units	Total=67 units	Total=30 units	Total=39 units
2	On-time delivery	95%	95%	95%	95%	95%	95%

As can see from table 4.1 and table 4.2 it shows that both year to month performance and plan report of the company respectively. Now compare the plan and actual performance as follows:

Table 4.3. Comparison of Plan vs Actual Performance.

Plan vs actual performance comparison														
S/N	KPIs		March		April		MAY		June		July		August	
			plan	actual	plan	actual	plan	actual	plan	actual	plan	actual	plan	actual
1	Throu-	FSR	12	2	12	6.75	14	2.74	12	7	11	10	11	6.4
		NPR	31	27	44	14.3	39	6.2	39	3.5	17	5.5	24	4
		Sino	6	1.5	6	0	7	0	6	0	1	0	1	0

	ghput	Trailer	6	3.15	6	4.5	7	1.35	6	0	1	0	1	0
		Total	55	33.5	68	25.5	67	10.3	63	1.5	30	15.5	37	11.4
2	On-time delivery		95 %	50%	95 %	44%	95 %	55%	95 %	50%	95 %	40%	95 %	53%

Table 4.4. Percentage Performed with Respect to the Target Plan.

Percentage Performed with Respect to the Target Plan													
S/N	KPIs	March		april		May		June		July		August	
		Plan	Percentage performed	Plan	Percentage performed	Plan	Percentage performed	Plan	Percentage performed	Plan	Percentage performed	Plan	Percentage performed
1	Throughput	55 units	60.80%	68 units	37.60%	67 units	15.35%	63 units	16.6%7	30 units	51.63%	37 units	30.80%
2	On-time delivery	95%	53%	95%	46.30 %	95%	57.89 %	95%	52.63	95%	42.10 %	95%	55.70 %

Throughput or production volume plan of the metal manufacturing factory is based on annual sales plan. As of the 2014 EC. Plan the metal manufacturing plan is 80.7% of the annual sales plan source (planning department of the company). But as can see from table 4the actual performance of the manufacturing workshop with respect to the plan of the last 6 month is 33.34%. This shows the productivity of the metal manufacturing workshop is very low and it needs enhancement.

As can see from table 4.4 the average on-time delivery is 48.667%. Even this figure is achieved by the sales department gives the delivery date to the customer beyond the standard production date of the product. For example, if the standard cycle time of the product is 8 days the sales department gives the delivery date to the customer is 10 days like this. Generally, the on-time delivery status of the company is very low and it needs to improve.

Table 4.5. Standard and Actual Cycle time for different product of the case company source reports from fabrication manager and customer relation of the company.

S/N	Product Name	Standard cycle time by two welders	Average actual consumed cycle time by the last 6-month of 2024 fiscal year	Variation between standard and actual cycle time (delay time)
1	FSR cargo body	12 working days	17 working days	5 working days
2	FSR van body	14 working days	17.5 working days	3.5 working days
3	FSR bus	60 working days	70 working days	10 working days
4	NPR cargo body	8 working days	11 working days	3 working days
5	NPR van body	10 working days	14.5 working days	4.5 working days
6	NPR bus	55 working days	65 working days	10 working days
7	Sino cargo body	8 working days	12 working days	4 working days
8	Trailer	21 working days	27 working days	6 working days

As can see from table 4.5 the average delay time of each product from the standard cycle time is 5.75 working days. It means a lot for both the customer and the company. By the company side this delay time will cost extra not only cost but the company will loss the revenue that can be generate by these delay time and by the customer side this delay time causes for customer dissatisfaction because this delay time will cause the customer to loss the revenue, they can generate by these delay time.

On the other side this delay time will not invite the customer to come again and this is highest business risk for one fabrication company. Therefore, the cycle time of each product has to be improved.

4.3. Production process of metal fabrication workshop

Figure 4.1. Metal manufacturing factory of the case company.

As can see from figure 4.1. Metal fabrication workshop is engaging with fabricating different cargo body mounted on Isuzu tracks, Sino tracks, and trailer. There are different product mix that are fabricated from this fabrication workshop. These are: -

- FSR Cargo Body
- FSR Van
- FSR Bus
- NPR Van
- NPR Bus
- NPR Cargo Body
- Sino Cargo Body
- Trailer

Table 4.6. Number of fabricated units by particular fiscal year corresponding with product mix.

Number of fabricated units by particular fiscal year						
S/N	Product name	2010(2017/18)	2011(2018/19)	2012(2019/20)	2013(2020/21)	2014(2021/22)
1	FSR cargo body	37	83	34	119	47
2	FSR van body	6	14	5	13	2
3	FSR bus	4	8	3	2	0
4	NPR cargo body	13	35	15	61	16
5	NPR van body	42	86	31	128	67
6	NPR bus	3	9	2	5	1
7	Sino cargo body	11	23	9	31	12
8	Trailer	15	32	12	15	19

As can see from table 4.6, there are basically eight types of product mix and four categories these categories are: -

1. Cargo body category: - this category includes dry cargo body mounted on different tracks like:-

- FSR cargo body
- NPR cargo body
- Sino cargo body

2. Van body category: - this category includes van body mounted on different tracks like: -

- NPR van
- FSR van

3. Bus category: - this category includes buses that are built on different tracks like: -

- FSR bus
- NPR bus

4. Trailer category: - this category includes different trailer families like: -

- High bed trailer
- Low bed trailer

As can see from table 4.6 also among these eight product mixes it is better to focus on products that have large volume of annual fabrication. Therefore, product that have large volume are: -

1. **FSR cargo body: -** it covers 29.9% from the total volume of the last five years production and the production process of cargo family product can addressed by this product and the percentage indicates that FSR cargo body has more customer demand.
2. **NPR van**: - it covers 33% from the total volume of the last five years production and the production process of van family product can addressed by this product and the percentage amount indicates that NPR van has more customer demand.
3. **Trailer**: - it covers 8.7% from the total volume of the last five years production and the production process of trailer family product can addressed by this product and product nature and production process is different and there is also large customer demand.

4.4. Fabrication process of FSR cargo body

FSR cargo body fabrication is conducted in the metal manufacturing factory of the company. Raw materials that are required for FSR cargo body production are: -

- Steel Sheet metals with the thickness range of 0.9mm up to 4mm
- Rectangular hollow section (RHS) with different size and thickness
- Angle iron with different size and thickness
- Flat iron with different size and thickness
- Galvanized pipe with different size and thickness
- U-channel with different size and thickness
- Round pipe with different size and thickness
- Hollow pipe with different size and thickness
- Wood
- Rubber belt
- Different bolt and nut with washer
- Cutting and grinding disks
- Welding electrode
- Mud flaps
- Hinges
- Drill bits

- Door locks
- And paintings etc.

By using the above raw materials, the fabrication process is explained as follows: - first the platform prepared from RHS and Angle iron then these RHS and Angle iron are cut as per the workshop drawing dimension and weld each other and then painted with anti-rust. Prepared platform is mounted on the FSR chassis by putting rubber belt and wood between the platform and chassis for dumping and friction purpose and doing joining process of platform and chassis by using bolt and nut tightening and fixed bracket welding. Then bended and cut sheet metal is placed over the platform and weld and front board also built on the platform. Side and rear board are prepared form bended and cut sheet metal and weld each other these boards will mount on the platform and floor assembly by using hinges and middle columns and painted with anti-rust. Extension board also prepared from RHS and painted with anti-rust and mounted the half sponda during assembly welding of hinges, sheet metals, looks and tightening of U-channel, L-bolt with nut are performed. And galvanized pipes are assembled over the extension board by welding. Then protection accessories and tool box will prepared and assembled. After all primary and final painting are performed and deliver to the finished product warehouse.

The work flow during FSR cargo body fabrication shows as follows: -

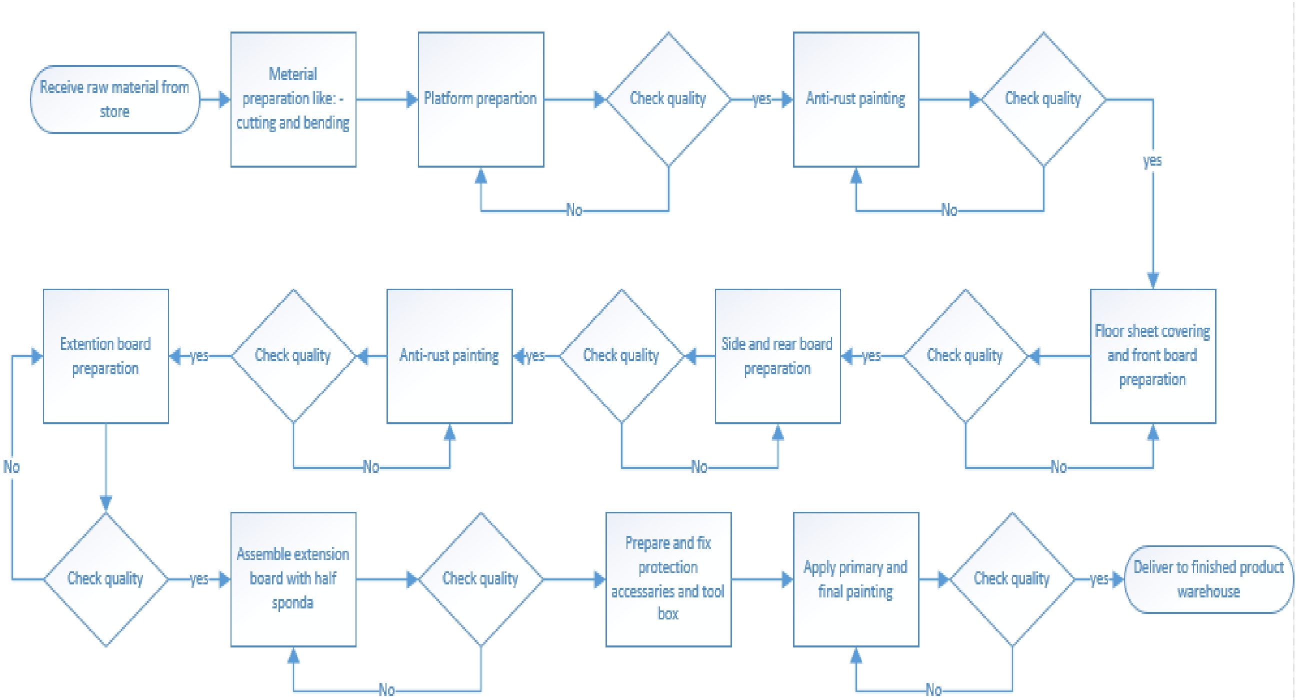

Figure 4.2. Work flow of FSR cargo body production.

4.5. Fabrication process of NPR van body

Figure 4.3. NPR van body.

As can see from figure 4.3 NPR van body fabrication is conducted in the metal manufacturing factory of the company. Raw materials that are required for NPR van body production are; -

- Steel sheet metal with different thickness range
- Aluminum sheet metal with different thickness
- Rectangular hollow section (RHS) with different size and thickness
- Angle iron with different size and thickness
- Flat iron with different size and thickness
- U-channel with different size and thickness
- Wood
- Rubber belt
- Different bolt and nut with washer
- Cutting and grinding disks
- Welding electrode
- Mud flaps
- Drill bits
- Door locks

- Rivets
- And paintings etc.

By using the above raw materials, the fabrication process is explained as follows: - first the platform prepared from RHS and Angle iron then these RHS and Angle iron are cut as per the workshop drawing dimension and weld each other and then painted with anti-rust. Prepared platform is mounted on the NPR chassis by putting rubber belt and wood between the platform and chassis for dumping and friction purpose and doing joining process of platform and chassis by using bolt and nut tightening and fixed bracket welding. Then bended and cut sheet metal is placed over the platform and weld. Then the main frame including side and rear doors are constructed on the platform assembly. Then side and roof sheet will covered by welding and painted with anti-rust and both primary and final painting. Then the internal surface of the van will covered by aluminum sheets by riveting. Then door lock accessories protection accessories fix. Finally deliver to the finished product warehouse.

The work flow during NPR van body fabrication shows as follows: -

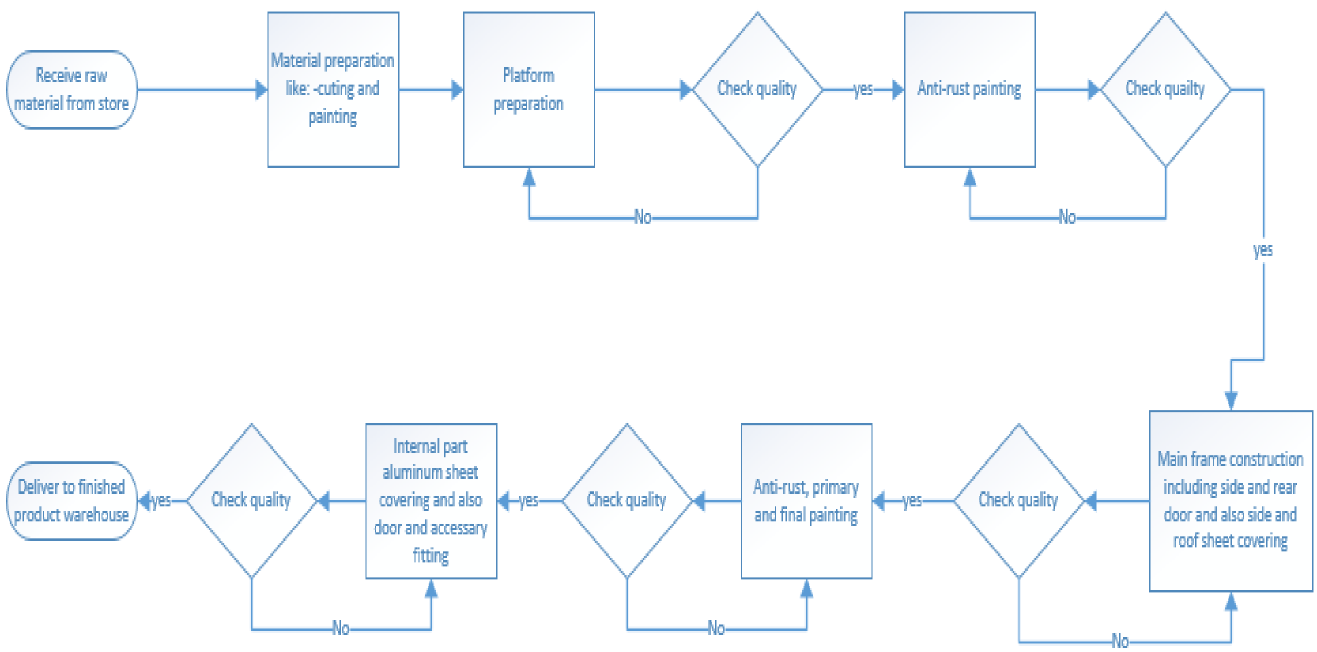

Figure 4.4. Work flow of NPR van body production.

4.6. Fabrication process of trailer

Trailer fabrication is conducted in the metal manufacturing factory of the company. Raw materials that are required for trailer production are; -

- Steel Sheet metals with the thickness range of 0.9mm up to 12mm
- Rectangular hollow section (RHS) with different size and thickness
- Flat iron with different size and thickness
- I-cross section beams with different size
- Galvanized pipe with different size and thickness
- U-channel with different size and thickness
- Round pipe with different size
- Round bar with different size
- Deformed bar
- Hollow pipe with different size and thickness
- Different bolt and nut with washer
- Cutting and grinding disks
- Welding accessary like: - electrode, welding wire, CO_2 gas, oxygen
- Mud flaps
- Hinges
- Drill bits
- Pins
- Rubber belt
- Draw bar accessories
- Hand and foot brake system accessories
- Lightening system accessories
- Suspension system like: - axle, wheel and tire, spring etc.
- Winch assembly
- And paintings etc.

By using the above raw materials, the fabrication process is explained as follows: - first main chassis will be prepared from sheet metal and I- beam will prepared the main operation is cutting, bending and welding. The trolley will prepared from I-beam the main operation is cutting and cutting. Main frame will be prepared and assembled with the main chassis and some accessary like winch will be prepared and assembled with the main frame. Then suspension plate will prepared. Then axle will prepared and ready for carrying the main chassis. Then the main chassis, trolley and frame assembly are mounted and assembled with the axle. Then turning table will be prepared the table will set and tight with bolt and nut and guide plate will be weld. Then the platform will prepared from small and big O-mega sheet and twist lock also prepared the main operation is cutting, bending and welding. Then floor sheet covering will be processed then side, front and rear board prepared and assembled over the platform assembly the main operation is cutting, bending and welding. Then spare wheel hunger, fuel tank support, tool box and rear bumper will prepared. Then draw bar assembly will prepared and assembled. Accessories like mud guard, light guard and others are prepared then fuel tank will be prepared. Then extension board will be prepared from RHS. The go for anti-rust, primary and final painting. Then lightening and air brake system will be installed. Then accessories and extension board are assembled with the main body. Finally deliver to finished product warehouse.

4.7. Analysis and evaluation of the manufacturing process by using value stream mapping (based on selected products)

As can see from table 4.5, the manufacturing lead time of the product is very large. Therefore, this portion was intended to evaluate the manufacturing process by using value stream mapping and identify the root cause for large production lead time.

Value stream mapping shows each step in the manufacturing process flow. From the map set up time, cycle time, inventory between each process step, the most type of wastes like un-necessary inventory, waiting, defect, and unnecessary motion and the production lead time.

4.7.1. Analysis of the current value stream map of NPR van production process

The value stream mapping of NPR van production process shows set up time, cycle time, inventory between each process step, and production lead time. The most type of waste NPR van production was a defect, waiting, unnecessary inventory, unnecessary motion and transportation.

To draw the current state of map the following points were considered: -

1. First understand the current production process flow sequentially.
2. Sketch the production process flow sequentially
3, record the production time by using stop watch
4. Follow the production process activity during the production time recording in order not to take invalid data
5. Encode the production time in to the sketched map.

Table 4.7. Average production time records of NPR van source direct visit records using stop watch.

s/no	Activity	Average Setup time in minute	Average operation time in minute	Average wasting time due to defect in minute	Average waiting time in minute	Average unnecessary inventory time in minute	Average movement waste time in minute
1	Issued material from the store				55	55	20
2	Material Preparation	25	720		250	40	15
3	plat form preparation	20	85		45	20	10
4	Check Quality	5	5	30			
5	Antirust painting	30	20		40	10	5
6	Floor sheet covering	28	75		40	20	10
7	Preparation of main frame	32	320		55	30	35
8	Check Quality	5	10	40			
9	Side, front, rear and roof sheet covering	20	720		45	40	20
10	Side and RR bumper	25	480		45	25	15

	preparation						
11	Check Quality	5	10	55			
12	Side and RR door preparation	30	480		45	30	15
13	Check Quality	5	8	40			
14	All Accessary Preparation	40	480		55	30	15
15	Washing and all type of painting	29	480		585	40	45
16	Aluminum sheet covering	45	480		45	45	15
17	Side and RR door J-rubber fitting and door lock fitting	30	140		45	30	10
18	Accessary fitting	30	100		150	25	20
19	Check Quality	5	20	55			
20	Total	408	4633	220	1510	440	250

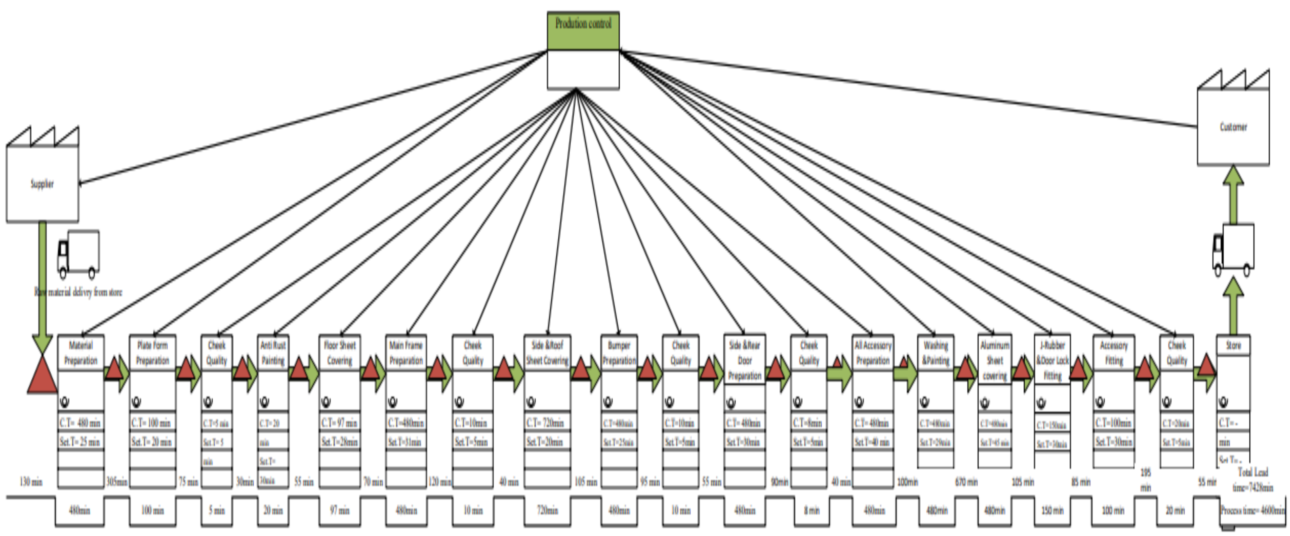

Figure 4.5. Current state VSM of NPR van production line

Table 4.8. Deadly wastes in the NPR van production with corresponding Lead times.

Type of deadly waste	Where it is observed in the current state map	Amount of time
Un-necessary	There is un-necessary inventory from satellite store for each	440 minutes

Inventory	process	
Un-necessary movement	There is un-necessary frequent motion of the technician from work station to satellite station for each process and there also movement of products from work station to painting station and accessary fitting station	250 minutes
Waiting	There is waiting for issued material form satellite store, material preparation and painting process and accessary fitting process	1510 minutes
defect	There is a rework due to defect from each process	220 minutes
Set up time	There is large set up time due to various work from one station and needs to do new set up for each process	408 minutes

As can see from table 4.8 from investigating the current state VSM these five deadly wastes were identified. Among these wastes waiting time was the largest waste in the process.

4.7.2. Root cause analysis of NPR van production process

A fishbone diagram is a visual way to look at the cause and effect. The problem or effect is displayed at the head of the fish. Possible contributing causes were listed on the smaller "bones "under various cause categories. A fishbone diagram can help identify a possible cause for a problem that might not otherwise be considered by directing the brainstorming –team to look at the categories and think of the alternative cause. The fishbone diagram was prepared to carefully investigate the cause that leads to the problem of large lead time of NPR van production

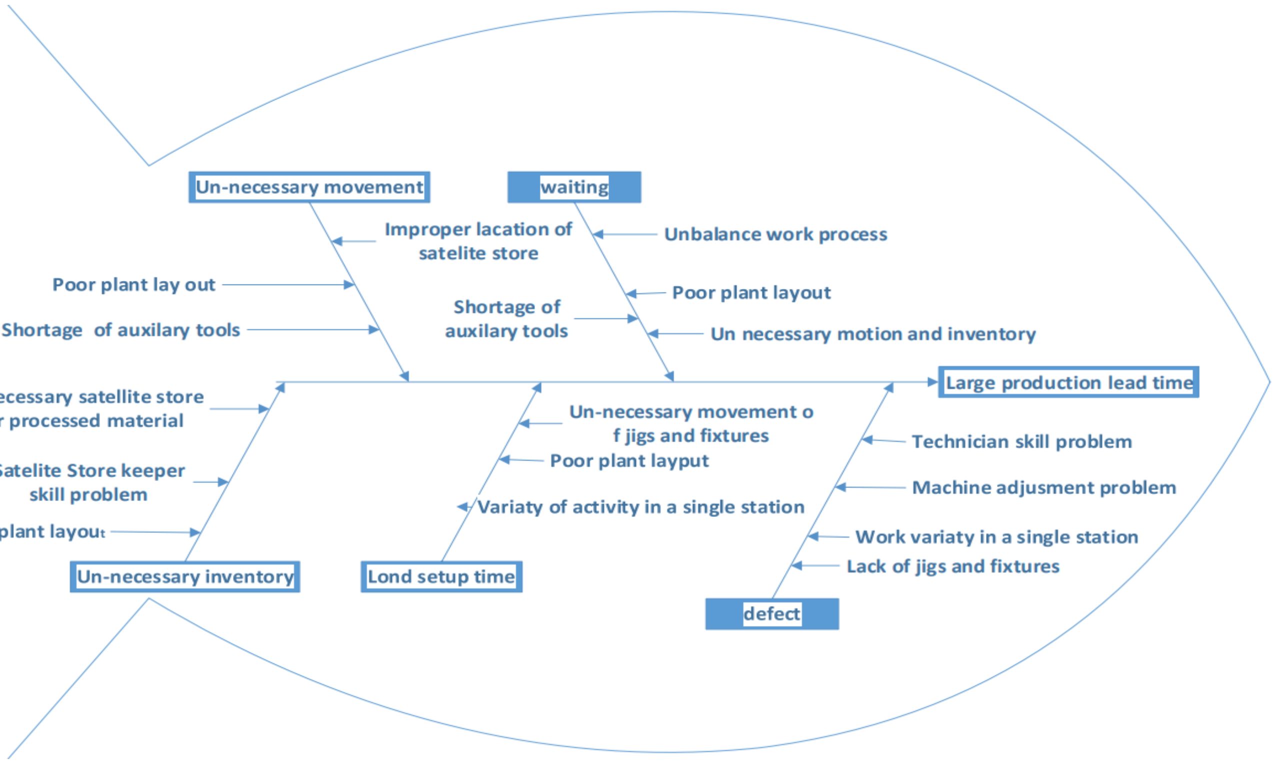

Figure 4.6. Cause and Effect Diagram of NPR van production line.

As can see from figure 4.6 there were various root causes for each individual deadly wastes in the process including: poor plan layout, unbalanced work process, variety of work in a single station, unnecessary satellite store and others.

4.7.3. Takt time and process efficiency calculation

Takt time is a calculation of the available production time divided by the customer demand. Whereas process efficiency is a calculation of the process time or operational time divided by the total lead time.

Takt time = available time/customer demand

Average customer demand per month is 33 units

Average Available time per month is 24 days or 192hrs

Takt time = 192hrs/33units = **5.8 hrs. per unit product**

Process efficiency = (process time/lead time) * 100%

As can see from table 4.8

Total setup time = 408minute

Total process time = 4633 minute

Total wasting time due to defect = 220 minute

Total waiting time = 1510minute

Total wasting time due to unnecessary inventory = 440minute

Total wasting time due to unnecessary movement = 250minue

So, total lead time = Total setup time + Total process time + Total wasting time due to defect + Total waiting time + Total wasting time due to unnecessary inventory + Total wasting time due to unnecessary movement

Total lead time = 408+4633+220+1510+440+250 = **7461minute**

Total process time **= 4633 minute**

Process efficiency = (4633minute/7461minute) * 100%

= 0.620*100%

= 62%

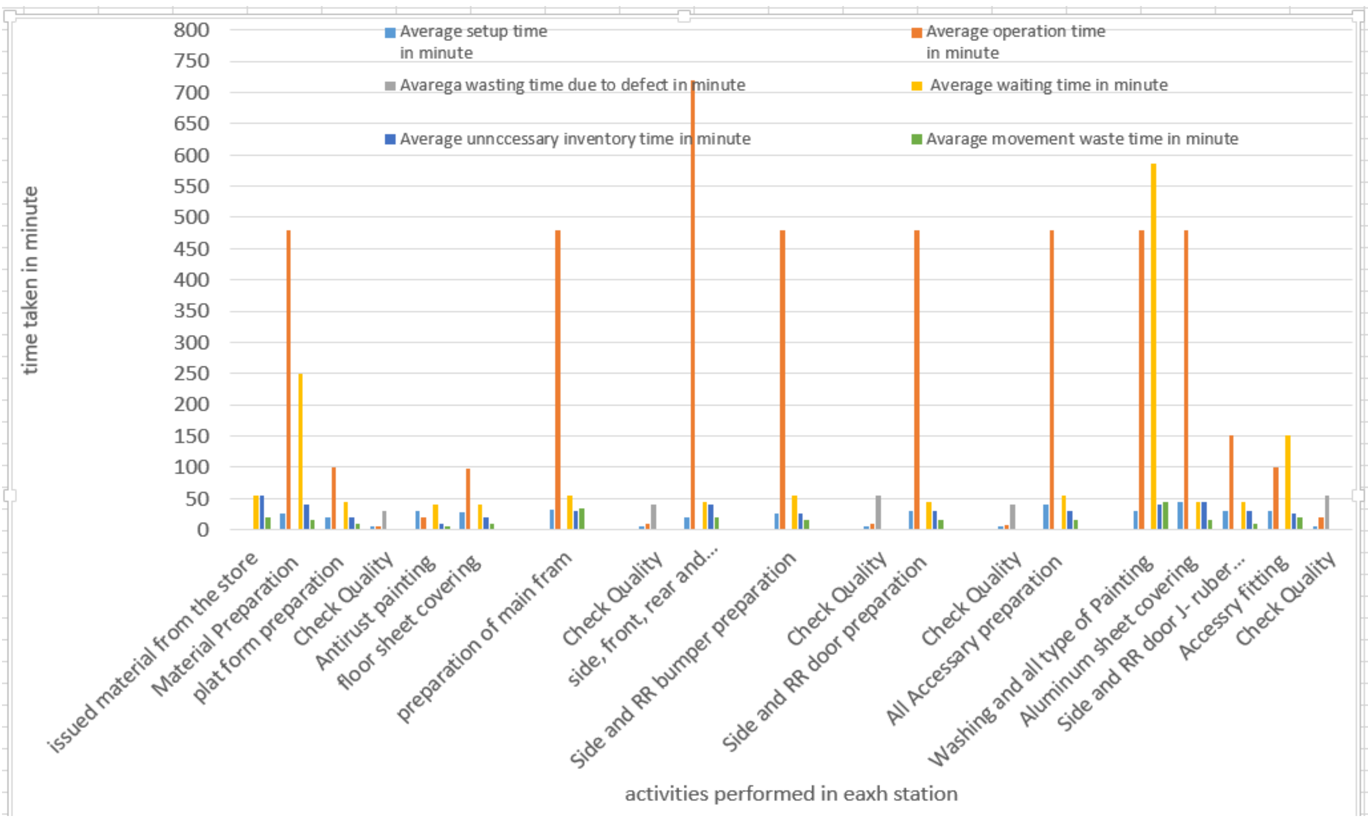

Figure 4.7. Performed activity vs time taken for NPR van production process.

As can see from figure 4.7 it describes the time taken vs each activity performed. So, from the figure is it observed that at material preparation, painting process and accessary fitting process were experienced large waiting time and considered as a bottleneck station.

Table 4.9. Analysis summery table for NPR van production line.

Total lead time	7461 minutes
Takt time	5.8hrs per unit product
Process efficiency	62%
Identified wastes	Waiting, un-necessary motion, un-necessary inventory, defect, long set up time
Bottle neck	Painting process, material preparation, accessary fitting

Table 4.9 shows the summery of the analysis of NPR van production process. The total lead time of the process is 7461 minutes, the Takt time of the product is 5.8 hrs or 348 minutes it means the process lead time is too much and the overall process efficiency is 62%. During the investigation there were five deadly wastes were identified. On the other hand there were three bottleneck station were identified these are: painting, material preparation and accessary fitting station.

4.7.4. Analysis of the current value stream map of FSR cargo production process

The value stream mapping of FSR cargo production process shows set up time, cycle time, inventory between each process step, and production lead time. The most type of waste FSR cargo production was a defect, waiting, unnecessary inventory, unnecessary motion and transportation.

To draw the current state of map the following points are mandatory: -

1. First understand the current production process flow sequentially.
2. Sketch the production process flow sequentially
3. Record the production time by using stop watch
4. Follow the production process activity during the production time recording in order not to take invalid data
5. Encode the production time in to the sketched map.

Table 4.10. Average production time records of FSR cargo source direct visit records using stop watch.

s/no	Activity	Average Setup time in minute	Average cycle time in minute	Average wasting time due to defect	Average waiting time in minute	Average wasting time in minute due to unnecessary inventory	Average wasting time in minute due to movement waste
1	Issued material from main store				60	50	30
2	Material Preparation	30	480		440	45	35
3	plat form preparation	25	240		35	25	10
4	Check Quality	5	10	30			
5	Floor sheet covering	28	130		35	25	10
6	Check Quality	5	8	20			
7	Front board preparation	20	130		40	30	10
8	Check Quality	5	5	20			
9	Side and rear board preparation	35	480		45	35	15
10	Check Quality	5	10	30			
11	Fixed bracket preparation	20	80		35	25	10
12	RR light protection preparation	20	140		35	25	10
13	Half sponda accessary preparation	40	240		55	40	20
14	Half sponda and front board	39	480		55	40	20

	assembling and ready for antirust						
15	Check Quality	5	20	40			
16	Washing and antirust painting of half sponda	30	480		300	20	10
17	Extension board preparation	50	1720		55	40	15
18	Antirust painting	14	20		20	15	10
19	Check Quality	5	10	50			
20	Extension board protection accessary prep	40	240		35	30	15
21	Assembling half sponda with extension board	40	480		55	40	20
22	Check Quality	5	10	40			
23	Final painting	50	720		965	25	20
24	Final Accessary Assembling	30	240		185	25	20
25	Final inspection	5	30	55			
26	Total	551	5403	285	2440	530	280

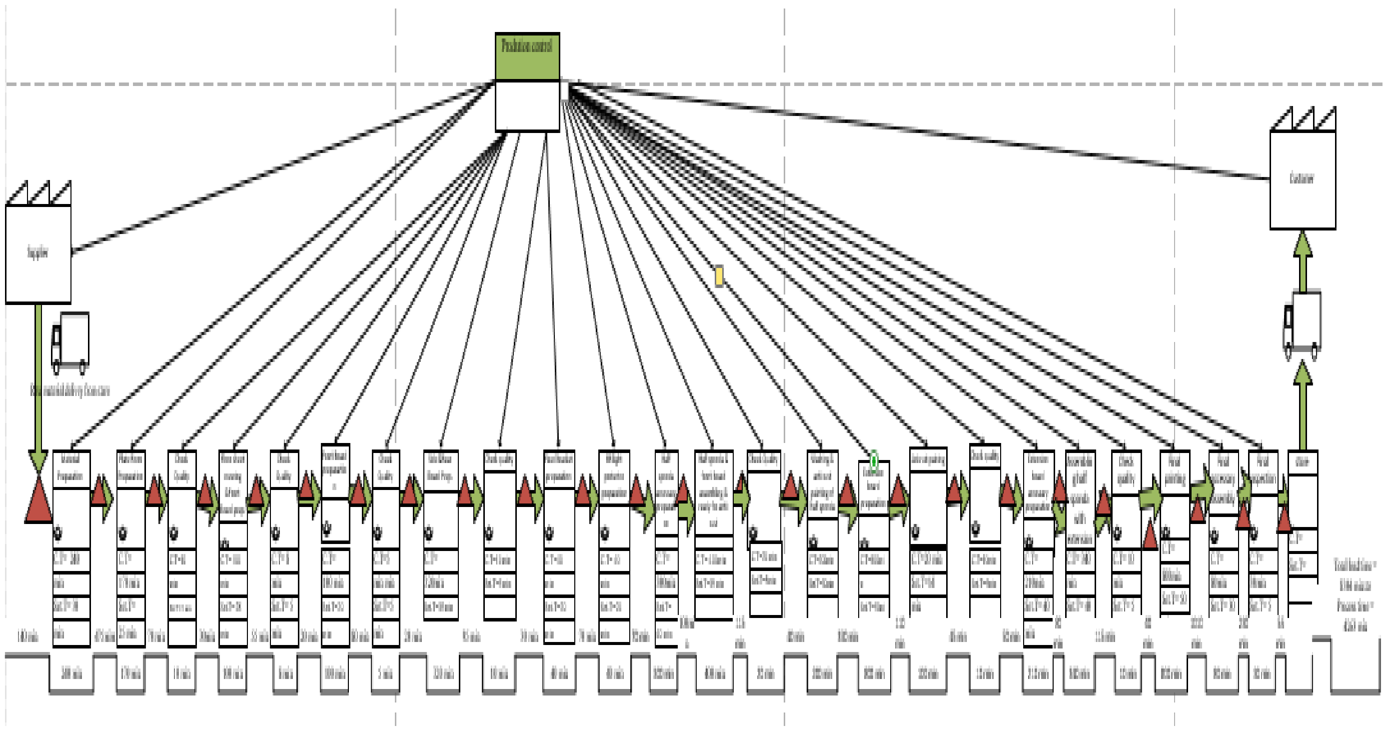

Figure 4.8. Current state VSM of FSR cargo production line.

Table 4.11. Deadly wastes in the FSR cargo production with corresponding Lead times.

Type of deadly waste	Where it is observed in the current state map	Amount of time
Un-necessary Inventory	There is un-necessary inventory from satellite store for each process	530 minutes
Un-necessary movement	There is un-necessary frequent motion of the technician from work station to satellite station for each process and there also movement of products from work station to painting station and accessary fitting station	280 minutes
Waiting	There is waiting for issued material form satellite store, material preparation and painting process and accessary fitting process	2440 minutes
defect	There is a rework due to defect from each process	285 minutes
Set up time	There is large set up time due to various work from one	551 minutes

	station and needs do new set up for each process.	

As can see from table 4.11 from investigating the current state VSM these five deadly wastes were identified. Among these five wastes waiting time was the largest one.

4.7.5. Root cause analysis of FSR cargo production process

A fishbone diagram is a visual way to look at the cause and effect. The problem or effect is displayed at the head of the fish. Possible contributing causes are listed on the smaller “bones “under various cause categories. A fishbone diagram can help identify a possible cause for a problem that might not otherwise be considered by directing the brainstorming –team to look at the categories and think of the alternative cause. The fishbone diagram was prepared to carefully investigate the cause that leads to the problem of large lead time of FSR cargo production.

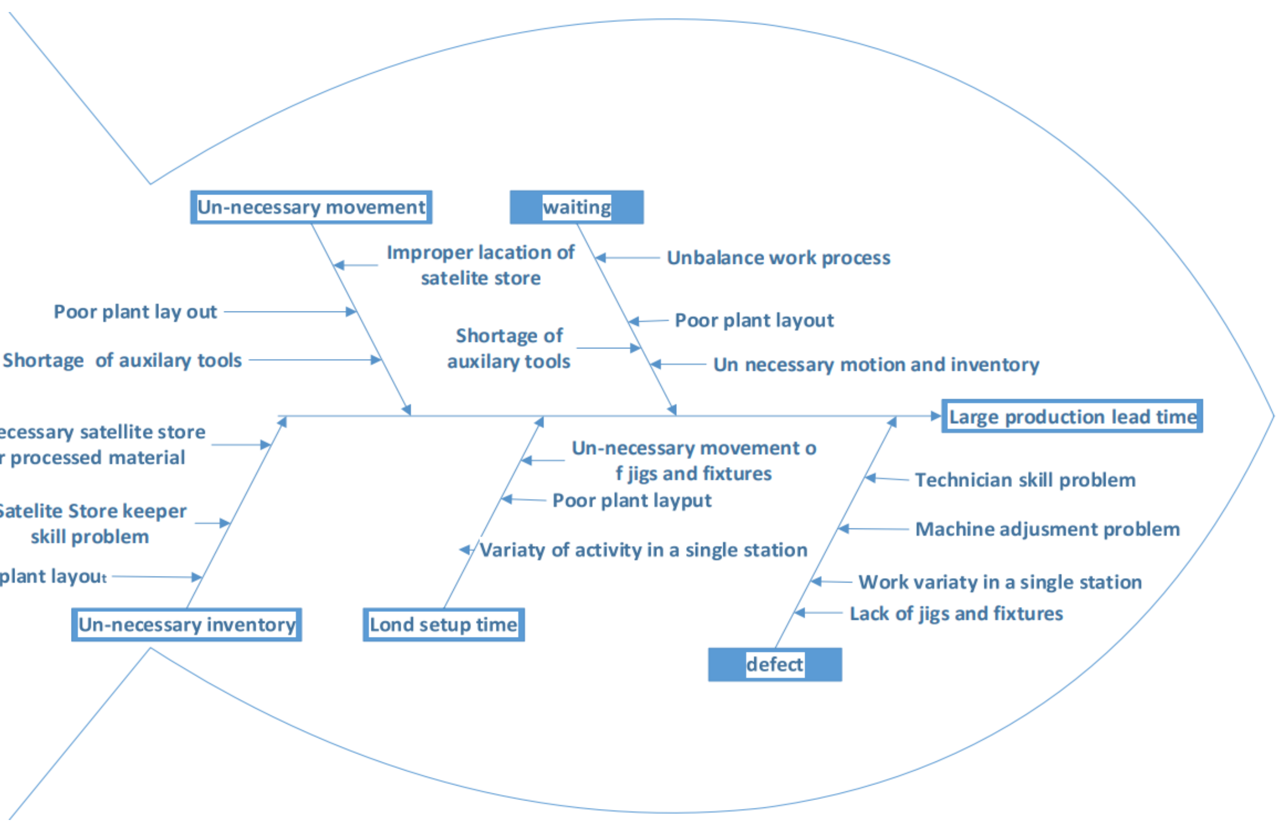

Figure 4.9. Cause and Effect Diagram of FSR cargo production process.

As can see from figure 4.9 there were various root causes for each individual deadly wastes in the process including: poor plan layout, unbalanced work process, variety of work in a single station, unnecessary satellite store and others.

4.7.6. Takt time and process efficiency calculation

Takt time is a calculation of the available production time divided by the customer demand. Whereas process efficiency is a calculation of the process time or operational time divided by the total lead time.

Takt time = available time/customer demand

Average customer demand per month is 12 units

Average Available time per month is 24 days or 192hrs

Takt time = 192hrs/12units = **16 hrs. Per unit product**

Process efficiency = (process time/lead time) * 100%

As can see from table 4.11

Total setup time = 551minute

Total process time = 54.3 minute

Total wasting time due to defect = 285 minute

Total waiting time = 2440minute

Total wasting time due to unnecessary inventory = 530minute

Total wasting time due to unnecessary movement = 280minue

So, total lead time = Total setup time + Total process time + Total wasting time due to defect + Total waiting time + Total wasting time due to unnecessary inventory + Total wasting time due to unnecessary movement

Total lead time = 551+5403+285+2440+530+280 = **9489minute**

Total process time **= 5403minute**

Process efficiency = (5403minute/9489minute) * 100%

= 0.569*100%

= 56.9%

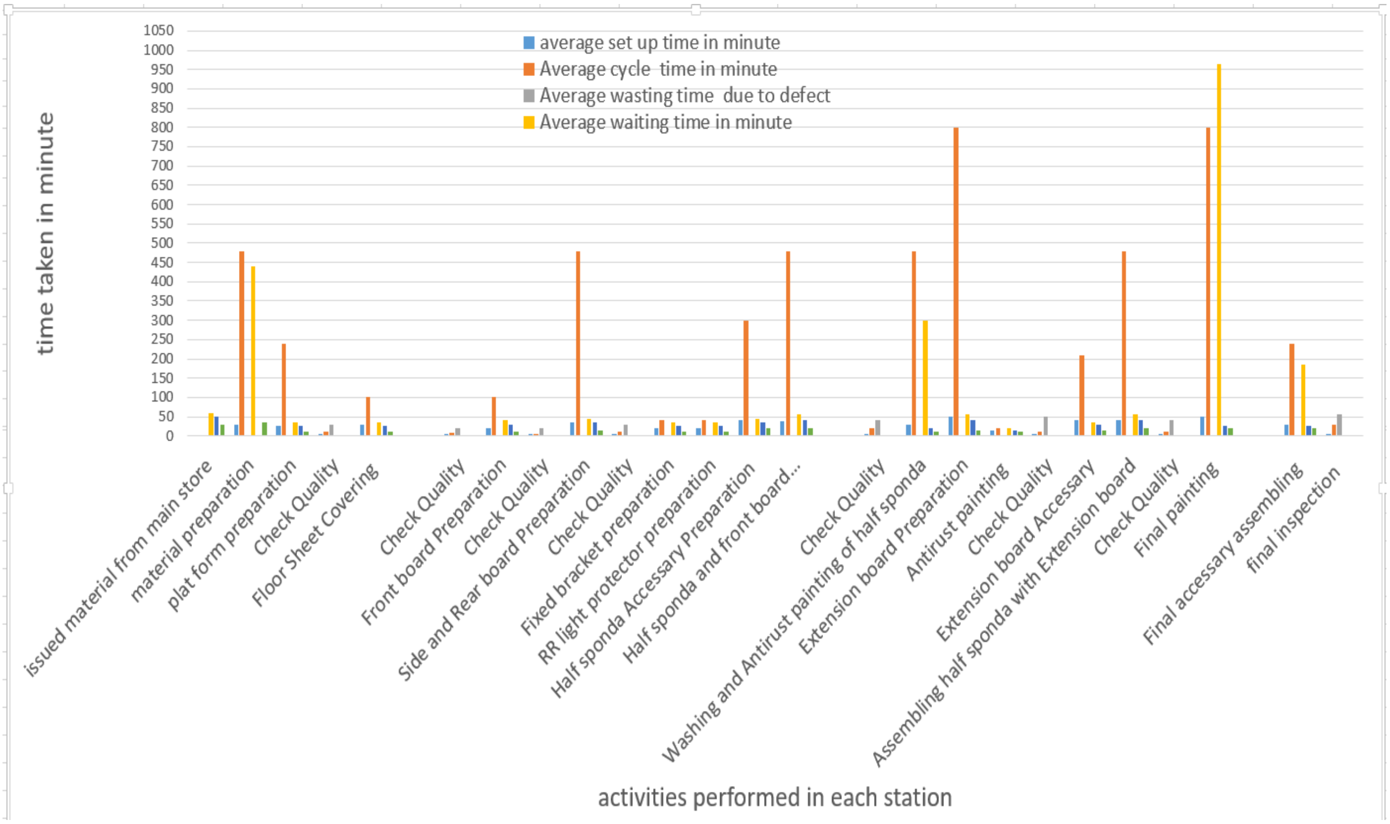

Figure 4.10. Performed activity vs time taken for FSR cargo production process.

As can see from figure 4.10 it describes the time taken vs each activity performed. So, from the figure is it observed that at material preparation, washing and anti-rust painting, final painting process and accessary fitting process were experienced large waiting time and considered as a bottleneck station.

Table 4.12. Analysis summery table for FSR cargo production process.

Total lead time	9489minute
Takt time	16 hrs per unit product
Process efficiency	56.9%
Identified wastes	Waiting, un-necessary motion, un-necessary inventory, defect, long set up time
Bottle neck	Final Painting, material preparation, accessary fitting and washing anti-rust painting of half sponda, extension board preparation.

Table 4.12 shows the summery of the analysis of FSR cargo production process. The total lead time of the process is 9489 minutes, the Takt time of the product is 16 hrs or 960 minutes it means the process lead time is too much and the overall process efficiency is 56.9%. During the investigation there were five deadly wastes were identified. On the other hand there were four bottleneck station were identified these are: material preparation, washing and anti-rust paiting, final painting and accessary fitting station.

4.7.7. Analysis of the current value stream map of Trailer production process

The value stream mapping of trailer production process shows set up time, cycle time, inventory between each process step, and production lead time. The most type of waste trailer production is a defect, waiting, unnecessary Inventory, unnecessary motion and transportation.

To draw the current state of map the following points are mandatory: -

1. First understand the current production process flow sequentially.
2. Sketch the production process flow sequentially.
3. Record the production time by using stop watch.
4. Follow the production process activity during the production time recording in order not to take invalid data.
5. Encode the production time in to the sketched map.

Table 4.13. Average production time for trailer fabrication source direct visit records using stop watch.

s/no	Activity	Average Setup time in minute	Average operation time in minute	Average wasting time due to defect	Average waiting time in minute	Average unnecessary inventory in minute	Average movement waste time in minute
1	Issued material from main store				70	90	60
2	Material Preparation	30	480		440	45	35

3	Chassis preparation, welding and assemble (preparation of I-beam, alignment and welding)	60	480		50	30	20
4	Check Quality	5	15	50			
5	Trolley preparation and welding	50	240		50	20	15
6	Check Quality	5	10	40			
7	Frame preparation, welding and assemble(preparation of winch and winch enforcement)	30	380		60	30	20
8	Check Quality	5	10	45			
9	Suspension plate preparation	20	240		100	25	20
10	Axle preparation, assemble and welding	50	1000		960	50	55
11	Check Quality	5	20	60			
12	Turning table preparation and assemble(turning table setting, tightening with bolt and nut and turning)	30	140		80	35	30
13	Check Quality	5	10	30			
14	Small and big omega preparation and welding (plat form preparation)	35	520		100	45	50
15	Check Quality	5	25	50			
16	Floor sheet metal	20	440		70	35	30

	covering and twist lock preparation						
17	Check Quality	5	15	35			
18	Front board, side board, rear board preparation and assemble(hinge preparation and welding)	30	1440		100	40	50
19	Check Quality	5	20	45			
20	Wheel carrier, rear bumper and tool box preparation and welding	25	580		105	40	55
21	Check Quality	5	25	30			
22	Fuel tank preparation and welding	20	240		80	35	40
23	Check Quality	5	20	40			
24	Connecting plate, draw bar preparation welding and assemble	30	480		100	45	50
25	Check Quality	5	10	50			
26	All accessary preparation	25	240		110	50	55
27	Check Quality	5	15	40			
28	Mud Guard, light guard and copper key support preparation, welding assemble	20	380		80	35	40

29	Check Quality	5	15	35			
30	Extension board preparation and welding	40	480		400	50	45
31	Check Quality	5	25	60			
32	painting	60	2160		2250	45	80
33	Check Quality	5	30	240			
34	Electric line installation and compressed air tank	30	480		110	55	50
35	Check Quality	5	35	45			
36	Assemble all accessary and extension board	35	480		300	50	45
37	Final check quality	5	40	60			
	Total	745	11720	955	5975	905	860

Table 4.13 shows each activities of trailer fabrication process with the detail breakdown time taken including the operational time and five deadly wastes. All the above data were collected by using stopwatch.

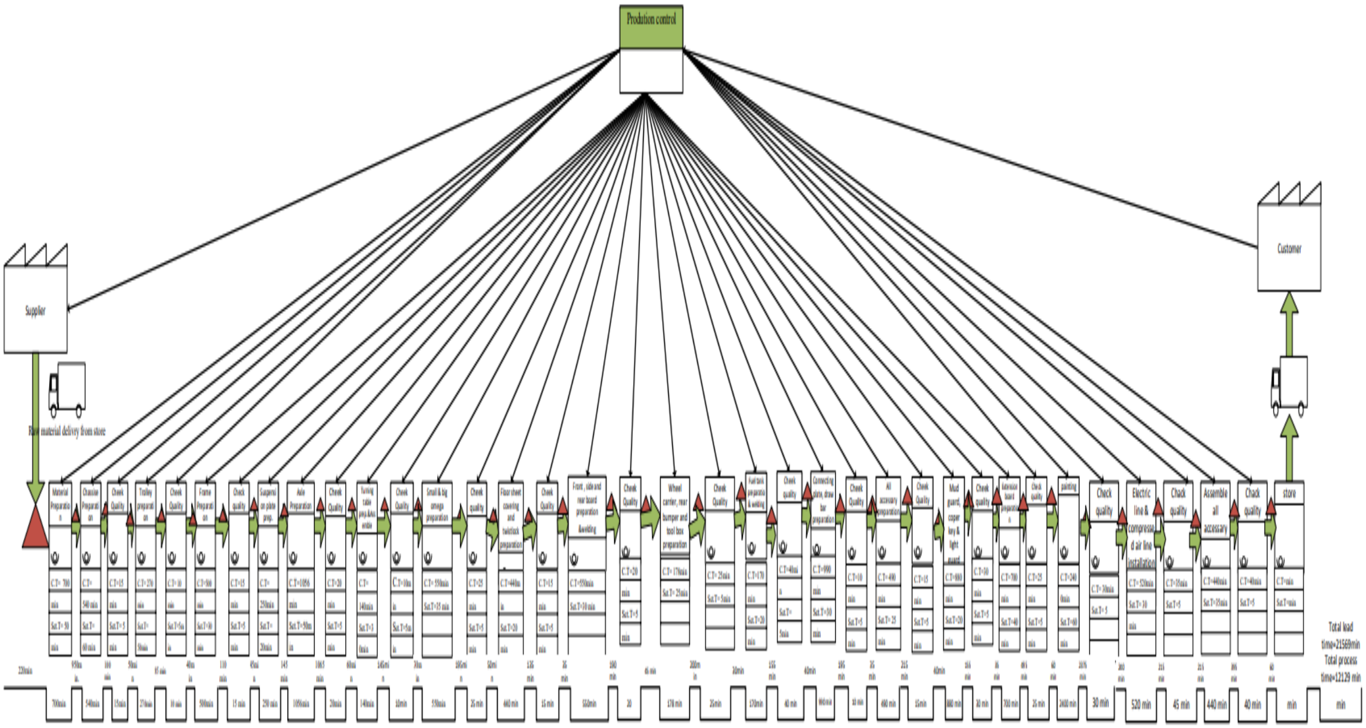

Figure 4.11. Current state VSM of trailer production line source direct visit record.

Table 4.14. Deadly wastes in the trailer production with corresponding Lead times.

Type of deadly waste	Where it is observed in the current state map	Amount of time
Un-necessary Inventory	There is un-necessary inventory from satellite store for each process	905 minutes
Un-necessary movement	There is un-necessary frequent motion of the technician from work station to satellite station for each process, unnecessary motion of painter from painting station to production station, unnecessary motion of jigs and fixtures and unnecessary motion for accessary fitting	860 minutes
Waiting	There is a large waiting for axle preparation and welding, painting, accessary fitting, material preparation and issued material form satellite store.	5975minutes
defect	There is a rework due to defect from each process	955minutes

Set up time	There is large set up time due to various work from one station and needs do new set up for each process. Like machine adjustment, jigs and fixtures adjustment etc.	745 minute

As can see from table 4.14 from investigating the current state VSM the following deadly wastes as denoted by lean are identified. Among these five wastes waiting time was the largest one.

4.7.8. Root cause analysis of trailer production process

A fishbone diagram is a visual way to look at the cause and effect. The problem or effect is displayed at the head of the fish. Possible contributing causes are listed on the smaller "bones "under various cause categories. A fishbone diagram can help identify a possible cause for a problem that might not otherwise be considered by directing the brainstorming –team to look at the categories and think of the alternative cause. The fishbone diagram was prepared to carefully investigate the cause that leads to the problem of large lead time of trailer production.

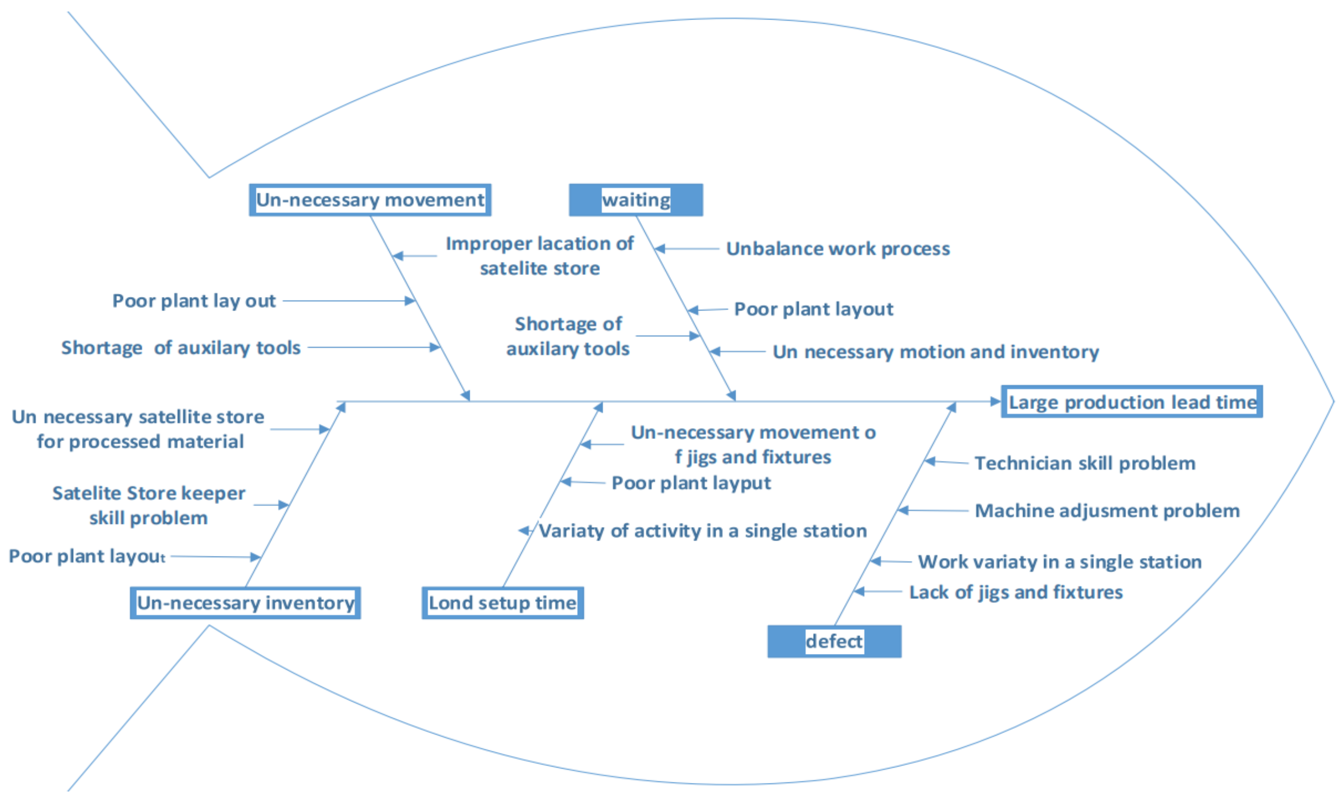

Figure 4.12. Cause and effect diagram of trailer production process.

4.7.9. Takt time and process efficiency calculation

Takt time is a calculation of the available production time divided by the customer demand. Whereas process efficiency is a calculation of the process time or operational time divided by the total lead time.

Takt time = available time/customer demand

Average customer demand per month is 5 units

Average Available time per month is 24 days or 192hrs

Takt time = 192hrs/5units = **38.4 hrs. Per unit product**

Process efficiency = (process time/lead time) * 100%

As can see from table 4.14

Total setup time = 745minute

Total process time = 11720 minute

Total wasting time due to defect = 955 minute

Total waiting time = 5975minute

Total wasting time due to unnecessary inventory = 905minute

Total wasting time due to unnecessary movement = 860minute

So, total lead time = Total setup time + Total process time + Total wasting time due to defect + Total waiting time + Total wasting time due to unnecessary inventory + Total wasting time due to unnecessary movement

Total lead time = 745+11720+955+5975+905+860 = **211600minute**

Total process time **= 11720minute**

Process efficiency = (11720minute/21160minute) * 100%

= 0.5538*100%

= 55.38%

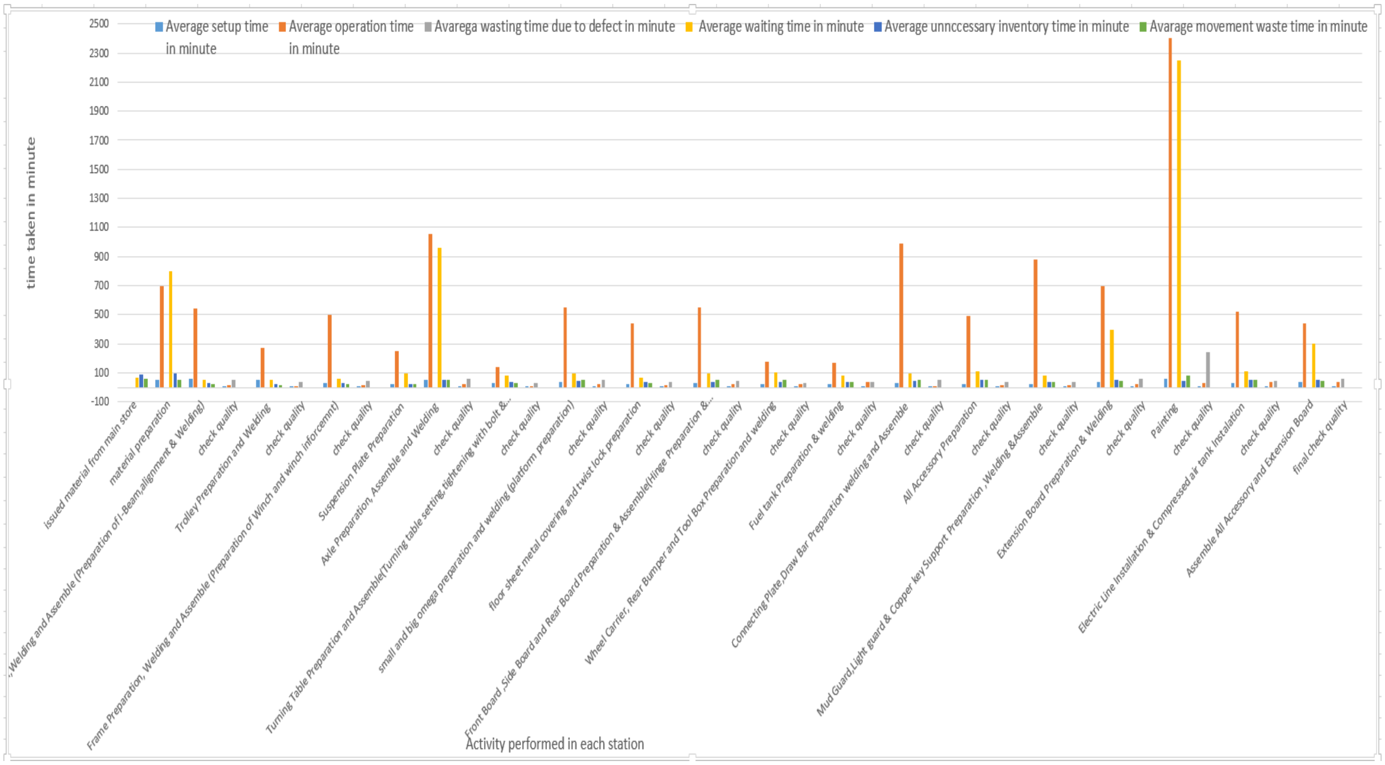

Figure 4.13. Performed activity vs time taken for trailer production process.

As can see from figure 4.13 it describes the time taken vs each activity performed. So, from the figure is it observed that at material preparation, axle preparation, extension board preparation, final painting process and assembling all accessary and extension board process were experienced large waiting time and considered as a bottleneck station.

Table 4.15. Analysis summery table for trailer production process.

Total lead time	21160minute
Takt time	38.4 hrs per unit product
Process efficiency	55.38%
Identified wastes	Waiting, un-necessary motion, un-necessary inventory, defect, long set up time
Bottle neck	Painting, material preparation, accessary fitting, extension board preparation, axle preparation, assembly and welding process

Table 4.15 shows the summery of the analysis of trailer production process. The total lead time of the process is 21160 minutes, the Takt time of the product is 38.4 hrs or 2304 minutes it means the process lead time is too much and the overall process efficiency is 55.38%. During the investigation there were five deadly wastes were identified. On the other hand there were four bottleneck station were identified these are: material preparation, axle preparation, extension board preparation, final painting and accessary fitting and extension board assembling station.

4.8. Questioner survey

This study employed a cross-sectional survey to investigate the root cause of waste of the case company that affect the Operational performance of metal cargo bodies and trailers fabrication. The root causes are: Production plant lay-out, Un-Balanced work process, Variety of activity in a single station, Un-necessary satellite store, Shortage of Auxiliary tools, Jigs and fixture, Worker's skill and Machine adjustment. The participants of this study were operators, Middle and Top managers, quality inspectors, and engineering teams at KAKI P.L.C. A well-designed questionnaire was distributed to 40 employees at the company. The collected data was then analyzed using (SPSS, Version 20). The primary source for determining the content of the questions was the current literature and most of questions used in this study were based on the previous studies. The survey consisted of two major sections. The first section is asked about the Assessment of waste of the case company that affect Operational performance of metal cargo bodies and trailers fabrication and were measured on a five-point Likert scale ranging from 1 "strongly Agree" to 5 "strongly Dis agree". In the second section employers were asked among the seven root causes which one highly affects the Operational performance of metal cargo bodies and trailers fabrication on a five-point Likert scale ranging from 1 "Very low" to 5 "Very High". In the following section, the analysis of results for the collected data is presented.

4.8.1. Questioner survey results

In this section, the findings are presented in the following analysis (1) Reliability Test (2) Descriptive analysis -mean and standard deviations (3) Inferential analysis the Pearson Correlation.

- **Reliability Test**

Below is the summarized Cronbach Alpha's Coefficient, Using George and Mallery (2003) rule of thumb any items with a value of less than 0.5 would be unacceptable, Root cause for low operational performance of metal cargo bodies & trailer fabrication measurement scale has demonstrated acceptable internal consistency reliability that with obtaining greater than 0.7 means reliable. Moreover, Nunnally (1978) reasoned that variable value approaching to 1.00 is reliable. Based on the summarized Cronbach alpha coefficient in from table 4.16 shows that most of the variable have exceeded the acceptable level respectively suggesting a good interim reliability.

Table 4.16. Cronbach's alpha results for each root cause of low operational performance of cargo bodies and trailer fabrication.

Root cause of wastes that affect Operational performance of cargo bodies & trailer fabrication	**Reliability Statistics**	
	Cronbach 's alpha	**No of Items**
Production plant lay out	0.918	4
Un-Balanced work process	0.865	3
Variety of activity in a single station	0.751	3
Un-necessary satellite store	0.947	3
Shortage of Auxiliary tools, Jigs and fixtures	0.732	3
Worker's skill	0.767	3
Machine adjustment	0.837	3

- **Descriptive Analysis**

Table 4.17 below tabulates the mean and standard deviation for Root cause of wastes that affect the Operational performance of metal cargo bodies & trailer fabrication. Production plant lay out has the highest mean score 4.18 and followed by mean score 3.85 for Un-Balanced work process as the second highest with close range with Variety of activity in a single station 3.75 and sequenced by Un-necessary satellite store, Shortage of Auxiliary tools, Jigs and fixtures, Worker's skill, Machine adjustment.

According to Zaidaton and Bagheri, (2009) the mean score below 3.39 was considered as low, the mean score from 3.40 up to 3.79 was considered as moderate and mean score above 3.8 was considers as high as illustrated by Comparison bases of mean of score of five-point Likert scale instrument.

Table 4.17. Mean and standard deviation for Root cause of wastes that affect the Operational performance of metal cargo bodies & trailer fabrication.

Root cause of wastes on Operational performance of cargo bodies & trailers	N	Minimum	Maximum	Mean	Standard Deviation
Production plant lay out	40	1	5	4.18	1.08
Un-Balanced work process	40	1	5	3.85	1.388
Variety of activity in a single station	40	1	5	3.75	1.410
Un-necessary satellite store	40	1	5	3.65	1.46
Shortage of Auxiliary tools, Jigs and fixtures	40	1	5	3.6	1.446
Worker’s skill	40	1	5	3.48	1.502
Machine adjustment	40	1	5	2.25	1.446

- **Inferential Analysis – Pearson Correlation**

Pearson Correlation used to determine the relationship between the independent and dependent variable. Pearson correlation (r) is between -1 and +1. That indicates the extent to which two variables are linearly related.

If r=1 perfectly positive correlation
If r=-1 Negative correlation
Correlation never higher than 1 & never lower than -1.
If $r < 0.1$ weak, $r < 0.5$ moderate, $r < 0.8$ strong and $r \geq 0.8$ Very strong

Table 4.18 shows that correlation between Independent variable (Production plant lay out, Un-Balanced work process, Variety of activity in a single station, Un-necessary satellite store, Shortage of Auxiliary tools, Jigs and fixtures, Workers skill, Machine adjustment) and Dependent variable (low Operational performance of metal cargo body& trailer fabrication) . the result indicates positive correlation between Production plant lay out and low Operational performance of metal cargo body& trailer fabrication (r=0.718), Un-balanced work process and low Operational performance of metal cargo body& trailer fabrication (r=0.632), Variety of activity in a single work station & low Operational performance of metal cargo body& trailer fabrication (r=0.629), Un-necessary satellite store and low Operational performance of metal cargo body& trailer fabrication (r=0.587), Shortage of auxiliary tools ,jigs & fixture and low Operational performance of metal cargo body& trailer fabrication (r=0.559), Workers skill and low Operational performance of metal cargo body& trailer fabrication (r=0.342). There is a negative correlation between Machine adjustment and low Operational performance of metal cargo body& trailer fabrication (r=-0.069).

Table 4.18. Correlation analysis b/n dependent and independent variable.

Correlations

		Pdn plant lay out	Un-Bal.work process	Variety of Activity	Un-necessary satelite store	Shortage of Aux. tools,jigs,fixture	Workers skill	Machine adjusteme nt	Operational performance of CB&T
Pdn plant lay out	Pearson Correlation	1	.478**	.550**	.535**	.754**	.288	-.119	.718**
	Sig. (2-tailed)		.002	.000	.000	.000	.072	.465	.000
	N	40	40	40	40	40	40	40	40
Un-Bal.work process	Pearson Correlation	.478**	1	.359*	.769**	.492**	.613**	.055	.632**
	Sig. (2-tailed)	.002		.023	.000	.001	.000	.734	.000
	N	40	40	40	40	40	40	40	40
Variety of Activity	Pearson Correlation	.550**	.359*	1	.260	.267	.247	-.049	.629**
	Sig. (2-tailed)	.000	.023		.105	.096	.124	.762	.000
	N	40	40	40	40	40	40	40	40
Un-necessary satelite store	Pearson Correlation	.535**	.769**	.260	1	.647**	.515**	-.053	.587**
	Sig. (2-tailed)	.000	.000	.105		.000	.001	.747	.000
	N	40	40	40	40	40	40	40	40
Shortage of Aux. tools,jigs,fixture	Pearson Correlation	.754**	.492**	.267	.647**	1	.358*	-.060	.559**
	Sig. (2-tailed)	.000	.001	.096	.000		.023	.713	.000
	N	40	40	40	40	40	40	40	40
Workers skill	Pearson Correlation	.288	.613**	.247	.515**	.358*	1	.107	.342*
	Sig. (2-tailed)	.072	.000	.124	.001	.023		.511	.031
	N	40	40	40	40	40	40	40	40
Machine adjustement	Pearson Correlation	-.119	.055	-.049	-.053	-.060	.107	1	-.069
	Sig. (2-tailed)	.465	.734	.762	.747	.713	.511		.670
	N	40	40	40	40	40	40	40	40
Operational performance of CB&T	Pearson Correlation	.718**	.632**	.629**	.587**	.559**	.342*	-.069	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.031	.670	
	N	40	40	40	40	40	40	40	40

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

4.9. Summary of the finding

From the above analysis it can be seen that the low operational performance of the case company is due to the problem of different internal factors. Based on the survey result the major cause for low operational performance of the case company is due to different wastes like waiting, movement, inventory, long set up time and defect.

From the detail root cause analysis results shows that the root cause for those wastes are un-necessary satellite store for processed parts, variety of activities in a single station, un-necessary movement of jigs and fixtures, shortage of jigs and fixtures, shortage of auxiliary tools, technicians skill problem, machine calibration problem, satellite store keeper skill problem, unbalanced work station and poor plat layout.

As can see from questioner survey results almost all listed root causes are playing a vital role for low operational performance of the case company. However, among those root causes the major problem is poor plant layout of the case company as can see from survey questioner result plat lay out scores the reliability test of cronbach's alpha value of 0.918, descriptive analysis the mean value is 4.18 and pearsons correlation r = 0.718. if the plant layout will improve most of the other root causes of the problem will be improved.

Chapter Five

5. Development of solution for operational performance enhancement

This chapter presents the basic means of operational performance improvement models for metal cargo body and trailer Fabrication Company. The development of improvement models was based on literature review and observational finding of the case company analysis.

Before selecting a particular operational performance improvement model or approaches, it needs to be clear in what, why, and how it is trying to achieve and this was involved raising several related questions, such as (Joseph, 2016).

- What was aiming to change, improve and what outcome to look for?
- What was the key driver for change; review, change of staff, system, and setup?
- What was the timescale for the change and what resources are required/ available?
- Did the improvement be holistic in organizational activities or designed for a specific task?
- What was the level of organizational staff involvement? Prokepnko (2016)

As it was conducted in the previous chapters, research is to be undertaken to decide on the approach or balance of approaches that would best suit situations for metal cargo body and trailer fabrication especially to the case company. It is unlikely that a single approach would address all the associated problems and it does not aim at providing definite information on each approach however it is about to choose the best to address the strategic objectives and the vital/main problems that are responsible for low operational performance in this context. The following model was drawn mainly from metal cargo body and trailer fabrication industries and these models can assist its users in evaluating the strengths and weaknesses of their operating system, targeting their improvement areas, setting up an action plan for improvements, and tailoring a special part to the needs of their firm.

5.1. Models used for developing a solution

5.1.1. Future Value stream mapping

As can see from the analysis evaluation part or from chapter 4 this model was play a vital role to evaluate the current fabrication process of the case company. It is also better model for the new proposed solution by constructing the future state of map for the selected products.

Therefore, after analyzing wastes in the system and applying the respective Lean tool to bring about improvement, the future value stream mapping (FVSM) was developed. The summery of non-value-added activities that were corrected accordingly is summarized in the bellow table 5.1.

Table 5.1. CVSM & FVSM to the corresponding identified wastes with proposed solution.

Types of waste identified	**CVSM**		**FVSM**
	Cause	**Effect**	
waiting	Unbalanced work process poor plant layout shortage of auxiliary tools unnecessary inventory and motion	Large lead time(extra time in the process) defect mess	Design new plant layout line balancing and having enough auxiliary tools, use fast dry anti-rust , use press machine in axle preparation, use jigs in extension board preparation
Long setup time	Variety work in a single station unnecessary movement of jigs and fixtures, poor plant layout lack of jigs and fixtures	Large lead time(extra time in the process)	Design new plant layout
Unnecessary movement	Unnecessary and improper location of satellite store shortage of auxiliary tools, poor plant layout	Large lead time(extra time in the process)	Design new plant layout Having enough auxiliary tools
Unnecessary inventory	Unnecessary satellite store for processed	Mess, Large lead time(extra time in the	Design new plant layout

	materials , poor plant layout Satellite store keeper skill problem	process)	Apply kanabing, apply 5s
defect	Variety work in a single station, machine adjustment problem, technician skill problem, lack of jigs and fixtures	Rework that leads wastage of both time and material	Design new plant layout Assign technicians accordingly and having good jigs and fixtures

5.1.2. Plant layout design

Facility design is a basic principle in the arrangement the layout of production facilities and work areas that utilize work areas to place machines or other production support facilities and facilitate the movement of materials so that they obtain good, safe and comfortable production processes and working conditions so that they can support efforts to achieve the company's basic objectives Plant layout and material handling are planning and integration of flow of components of a product to get the most effective and economical interrelation between workers, equipment and material handling, beginning from the reception, through manufacturing, to the delivery of finished products (Tarigan et al. (2019).

- **Existing Plant Layout**

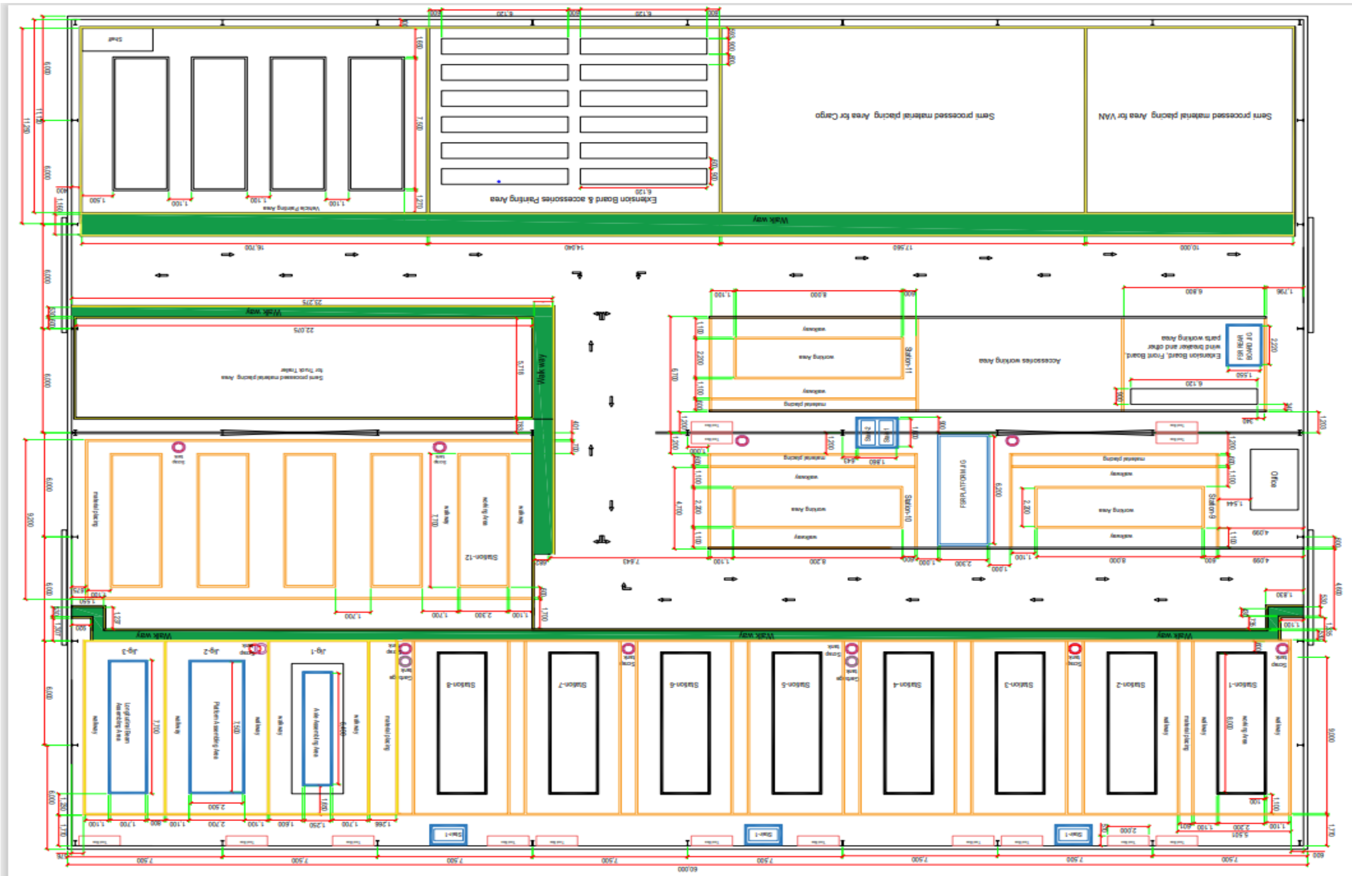

Figure 5.1. Existing plant layout of the case company.

Figure 5.1 shows the existing overall plant layout of the metal fabrication plant of the case company. And the category or type of layout is fixed position layout. So, from each station one product type supposed to be finished from end to end except painting work. There were 12 working station and 1 accessary fitting station which were used for different van, bus and cargo bodies mounted of Isuzu vehicles. From each station various products were built since it was a fixed position layout. Because of this 3/8th space of the factory was used for storage of semi-processed materials. On the other hand the nature of the product was not convenient for fixed position layout. Since the product output is the cumulative result of different activities. This situation leads the company in to various wastes like: waiting time, unnecessary movement and space utilization, inventory defect and others. Approximately 1/8th space of the factory is was is occupied by painting process. But, it supposed to be out of the factory with oven which is very important for various reasons including: better operational performance, painting quality and the health of the workers. And the remaining 2/8th space of the factory occupied by trailer fabrication process among these 3 stations are used for jigs placement for trailer part fabrication, one station used for processed material storage which also extravagance both time and space.

Generally the current plant layout of the factory was not convenient and efficient and leads the company to various deadly wastes.

- **New plant layout design**

As can see from the summery of finding the major root cause for low operational performance of the case company is having poor plant layout. The current plant layout of the case company is fixed position type layout and the new design layout is product layout. So, in order to design new plant layout there are various methods. Those are product family identification and activity relationship chart mode Lista et al. (2021). And CORELAP algorism model Tarigan et al. (2019). By using these models, the new plant layout will design.

By the principle of product family identification, the company has different types of product mix. Those are cargo product family, van body product family, and trailer product family and then each product family can be manufactured by using one cargo product family product layout, one van body product layout and one trailer product layout. Hence from this paper for cargo product FSR cargo product layout will design, for van body product NPR van product layout will design and trailer product layout will design.

- **NPR van product layout**

During designing product layout, it is mandatory to know each activity of the whole process. NPR van body fabrication processes have numerous activities such as:

Table 5.2. List of activities of NPR van body production process.

Material preparation (cutting and bending)	Rear bumper preparation
Platform preparation	Fender preparation
Anti-rust painting of platform	washing
Floor sheet covering	Anti-rust painting
Main frame preparation	Primary painting
Side sheet covering	Final painting

Front sheet covering	Internal aluminum sheet covering
Rear sheet covering	Side door J-rubber fitting
Roof sheet covering	Rear door J-rubber fitting
Side door preparation	Accessary fitting
Rear door preparation	
Side bumper preparation	

As can see from table 5.2 there were 22 different activities are involved on NPR van production. Now by using CORELAP algorism or activities relationship principle those 22 activities are merged to 9 working station.

Considerations during merging process: -

- production sequence: -this is very mandatory the process should not be go back
- Similarity activities: - activities which are demand the same working facility are place at the same station

Therefore, by considering the above situations those activities were merged as follows: -

Table 5.3. List of activities of NPR van after merging.

Station No	List of activities
1	Material preparation
2	Platform preparation, floor sheet covering and main frame preparation
3	Side, rear, front and roof sheet covering
4	Preparation of rear and side door
5	Side and rear bumper and fender preparation
6	Accessary preparation
7	Washing, anti-rust painting, primary and final painting
8	Apply internal aluminum sheet cover
9	Accessary fitting

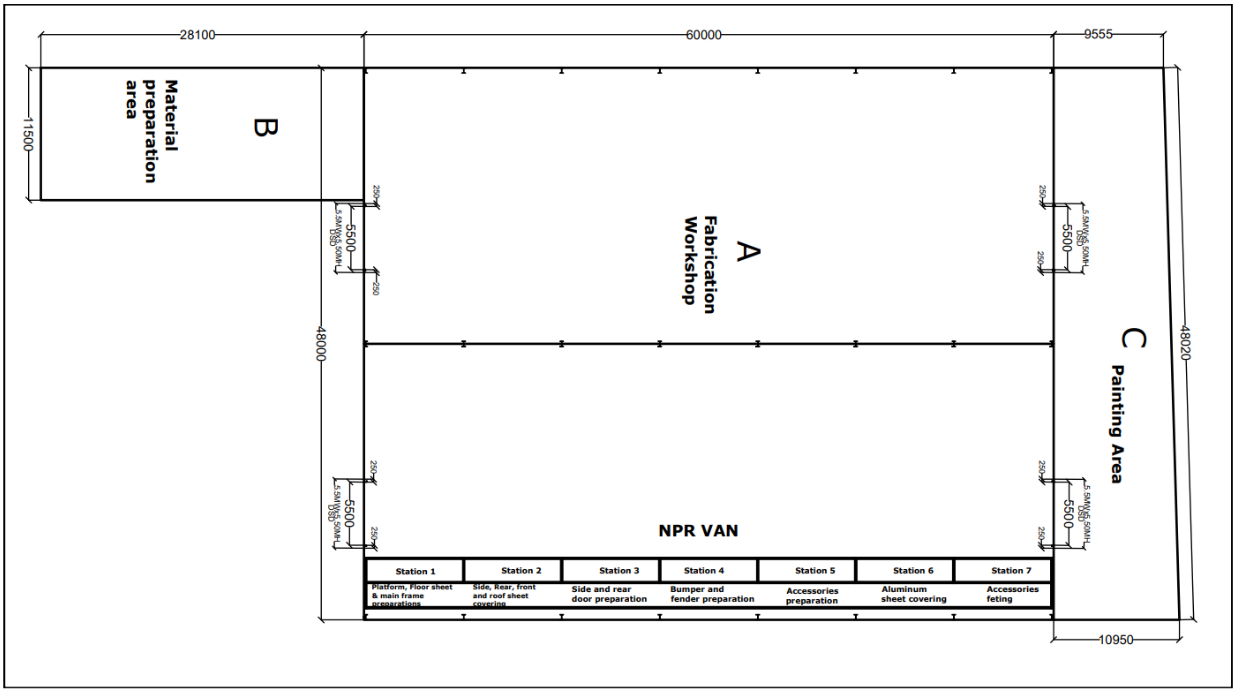

Figure 5.2. Newly developed NPR van product layout.

- **FSR cargo product layout**

FSR cargo production process has the following list of activities these are: -

Table 5.4. List of activities of FSR cargo production process.

material preparation (cutting and bending)	washing
Platform preparation	Anti-rust painting
Floor sheet covering	Extension board preparation
Front board preparation	Anti-rust painting
Side board preparation	Extension board accessary preparation
Rear board preparation	Assemble half sponda with extension board
Fixed bracket preparation	Primary painting
Rear light protector preparation	Final painting
Half sponda accessary preparation	Accessary fitting
Assemble half sponda with front board and ready for anti-rust	

As can see from table 5.4 there are 19 different activities are involved on FSR cargo production. Now by using CORELAP algorism or activities relationship principle those 19 activities were merged to 11 working station.

Considerations during merging process: -

- Production sequence: -this is very mandatory the process should not be go back
- Similarity activities: - activities which are demand the same working facility are place at the same station

Therefore, by considering the above situations those activities are merged as follows: -

Table 5.5. List of activities of FSR cargo after merging.

Station No	List of activities
1	Material preparation
2	Platform preparation
3	Floor sheet covering, front board, rear light protector and fixed bracket preparation
4	Side and rear board preparation
5	Assemble side and rear board with front board
6	Washing and anti-rust painting
7	Extension board preparation
8	Assemble half sponda with extension board
9	Preparation of all accessary
10	Primary and final painting
11	Accessary fitting

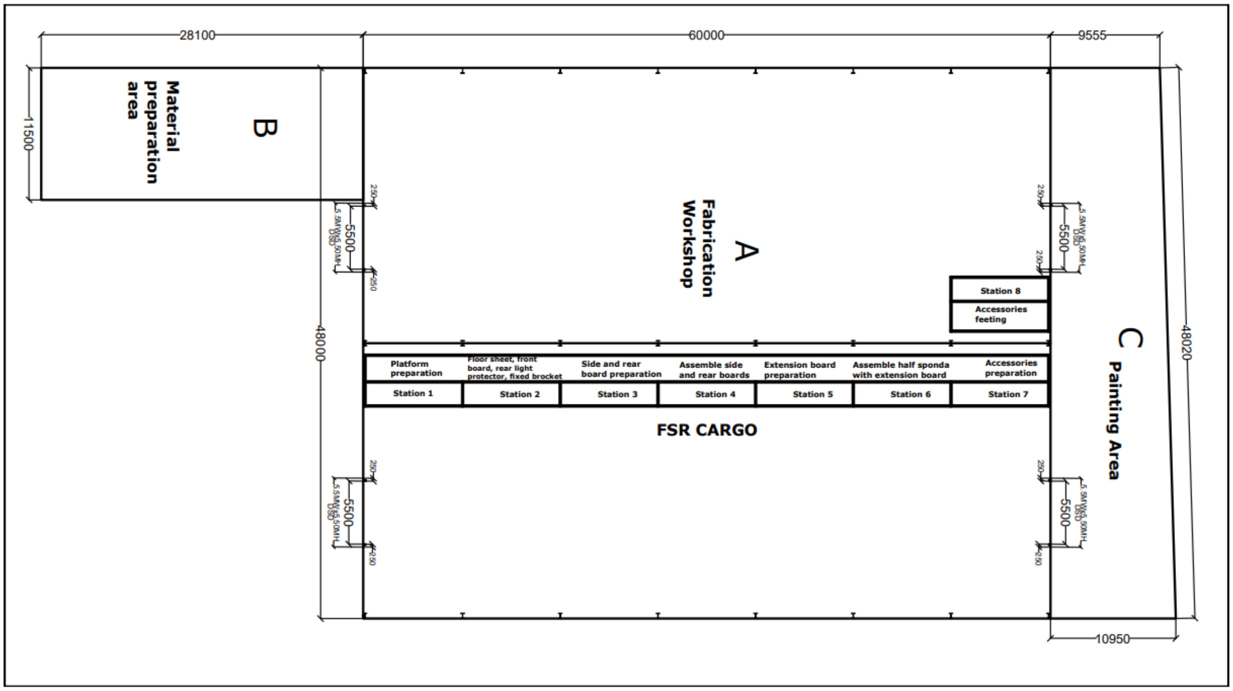

Figure 5.3. Newly developed FSR cargo product layout.

➢ Trailer product layout

Trailer production process has the following list of activities: -

Table 5.6. List of activities of trailer production process.

Material preparation (cutting & bending)	Rear bumper preparation
Chassis preparation	Tool box preparation
I-beam preparation	Fuel tank preparation
Trolley preparation	Connecting plate preparation
Frame preparation	Draw bar preparation
Winch preparation	All accessary preparation
Suspension plate preparation	Mud guard preparation
Axle preparation	Light guard preparation
Turning table preparation	Copper key support preparation
Platform preparation	Extension board preparation
Floor sheet covering	washing

Twist lock preparation	Primary painting
Front board preparation	Final painting
Side board preparation	Electric line installation
Rear board preparation	Compressed air tank installation
Hinge preparation	Accessary fitting
Wheel carrier preparation	Extension board assembly

As can see from table 5.6 there are 34 different activities are involved on Trailer production. Now by using CORELAP algorism or activities relationship principle those 34 activities were merged to 12 working station.

Considerations during merging process: -

- Production sequence: -this is very mandatory the process should not be go back
- Similarity activities: - activities which are demand the same working facility are place at the same station

Therefore, by considering the above situations those activities are merged as follows: -

Table 5.7. List of activities of trailer after merging.

Station No	List of activities
1	Material preparation (cutting and bending)
2	Main chassis, frame, winch, hook & turning table preparation
3	Platform and twist lock preparation and floor sheet covering
4	Axle and trolley preparation
5	Side, rear & front board preparation
6	Wheel carrier and fuel tank preparation
7	Rear bumper, mud guard, light guard, copper key supper & other accessary preparation
8	Connecting plate & draw bar preparation
9	Extension board preparation
10	Washing & painting
11	Electric line and compressed air tank installation
12	Accessary and extension board assembly

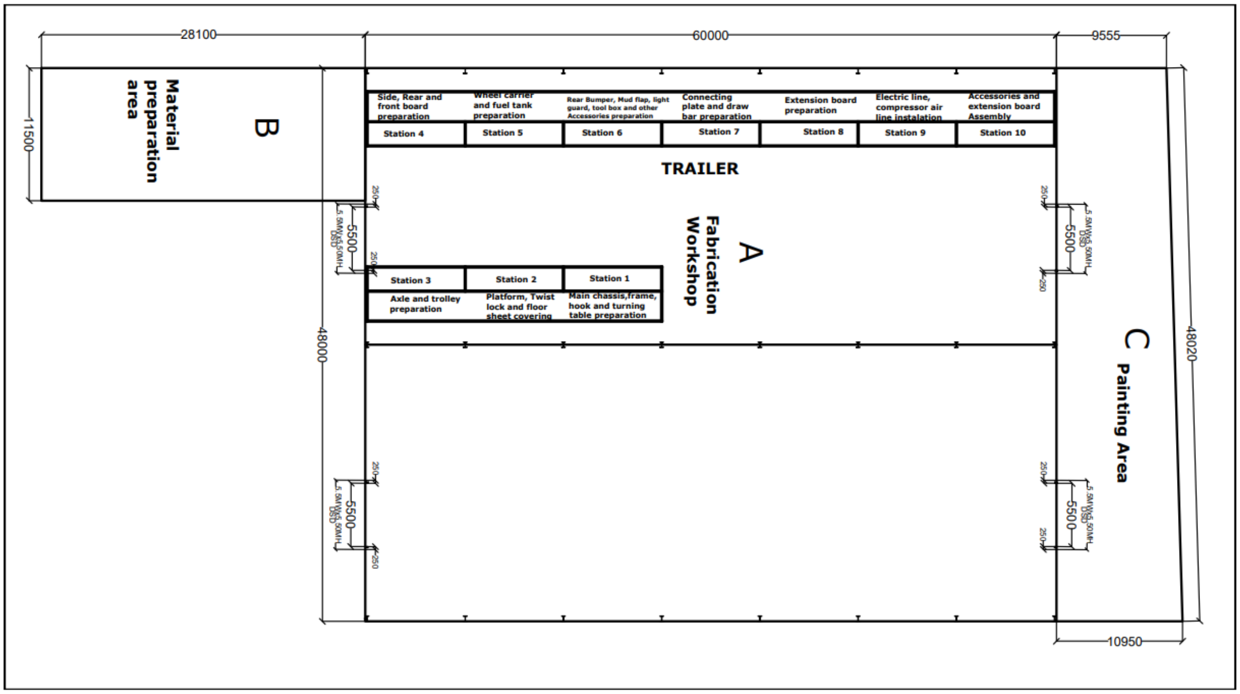

Figure 5.4. Newly developed Trailer product layout.

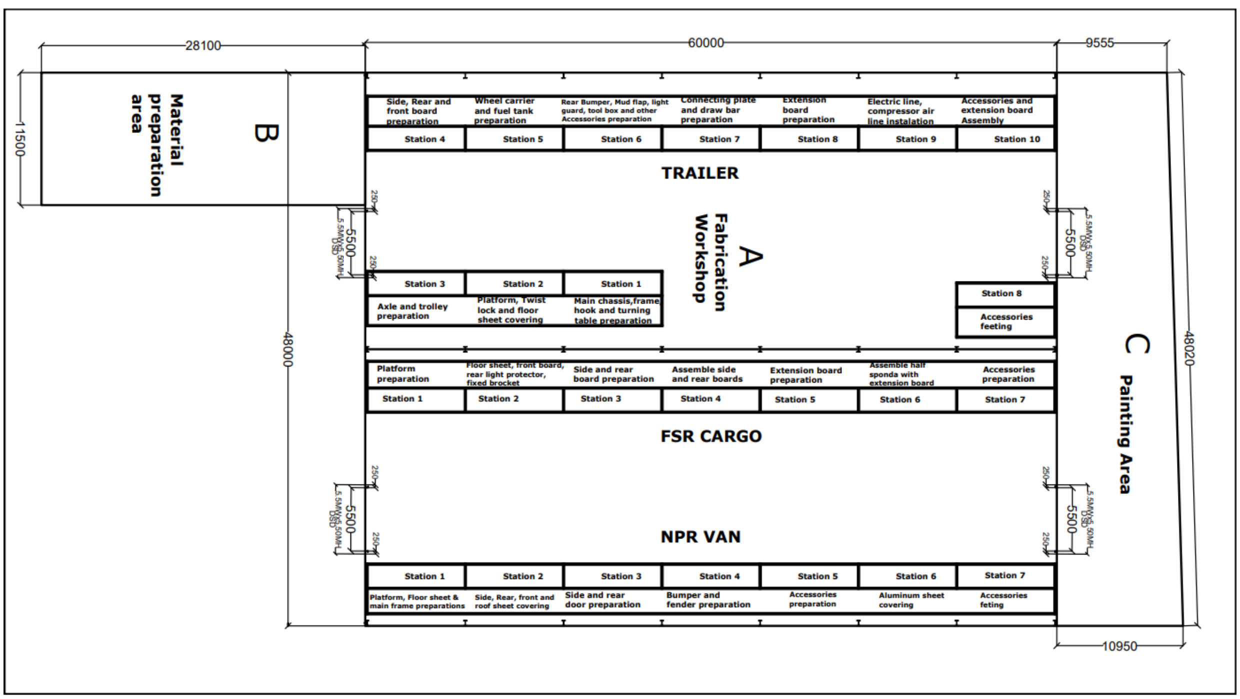

Figure 5.5. Newly developed over all fabrication plant layout.

- **Future value stream mapping of NPR van**

It is better to model the new developed solution by constructing the future state of map selected products. The future state of map is mapped based on the new plant layout. Therefore the new NPR van fabrication process with the corresponding operational time and intended deadly wastes are expressed as below table 5.8.

Table 5.8. Average production time of NPR van by new plant layout.

s/no	Activity	Average Setup time in minute	Average operation time in minute	Average wasting time due to defect in minute	Average waiting time in minute	Average unnecessary inventory time in minute	Average movement waste time in minute
1	Issued material from main store				30	20	15
2	Material Preparation	20	480		25	15	35
3	Main frame preparation and floor sheet covering	10	240		13	8	5
4	Check Quality	5	10	15			
5	Front, rear, side and roof sheet covering	10	720		13	8	5
6	Check Quality	5	10	15			
7	Preparation and assembly of rear and side doors	20	130		40	30	10
8	Check Quality	5	5	20			
9	Side and rear board preparation	10	480		13	8	5

10	Check Quality	5	10	20			
11	Preparation of all accessary	10	480		13	8	5
12	Check Quality	5	10	15			
13	Washing, anti-rust and final painting	10	480		480	10	5
14	Check Quality	5	10	20			
15	Apply internal Aluminum sheet covering	10	480		13	8	5
16	All Accessory assembly	10	240		13	8	5
17	Final check quality	5	10	20			
	Total	135	4390	120	626	101	65

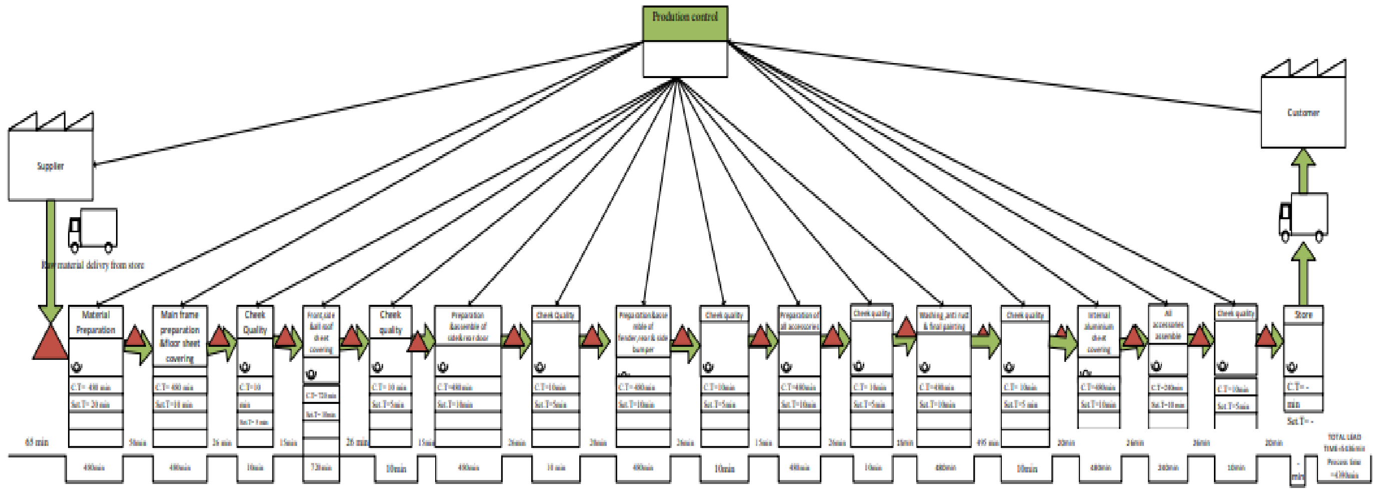

Figure 5.6. Future value stream map of NPR van.

As can see from figure 5.6 it describes about the future state map of NPR van fabrication process which is based on the new designed plant layout. From the map it was observed that the detail activities with the corresponding time taken. The total lead time was observed at the end of the process.

- **Takt time and process efficiency calculation after layout improvement**

Takt time is a calculation of the available production time divided by the customer demand. Whereas process efficiency is a calculation of the process time or operational time divided by the total lead time.

Takt time = available time/customer demand

Average customer demand per month is 33 units

Average Available time per month is 24 days or 192hrs

Takt time = 192hrs/33units = **5.8 hrs. per unit product**

Process efficiency = (process time/lead time) * 100%

As can see from table 5.8: -

Total setup time = 135minute

Total process time = 4390 minute

Total wasting time due to defect = 120 minute

Total waiting time = 626minute

Total wasting time due to unnecessary inventory = 101minute

Total wasting time due to unnecessary movement = 65minue

So, total lead time = Total setup time + Total process time + Total wasting time due to defect + Total waiting time + Total wasting time due to unnecessary inventory + Total wasting time due to unnecessary movement

Total lead time = 135+4390+120+626+101+65 = **5437minute**

Total process time **= 4390 minute**

Process efficiency = (4390minute/5437minutes) * 100%

= 0.8074*100%

= 80.74%

- **Takt time and process efficiency calculation after layout improvement and applying oven on the painting process**

Currently the time required for painting is by three painters is 12 hrs. But, among these 12 hrs operational time is 3 hrs and the other 9 hrs are required for drying. Then by using oven the drying time can be reduced by 66 percent source (NA engineering practical experience).

Therefore, the waiting time is reduced by 66% and the process efficiency is calculated as follows.

Total setup time = 135minute

Total process time = 4390 minute

Total wasting time due to defect = 120 minute

Total waiting time = 212minute

Total wasting time due to unnecessary inventory = 101minute

Total wasting time due to unnecessary movement = 65minue

So, total lead time = Total setup time + Total process time + Total wasting time due to defect + Total waiting time + Total wasting time due to unnecessary inventory + Total wasting time due to unnecessary movement

Total lead time = 135+4390+120+212+101+65 = **5023minute**

Total process time **= 4390 minute**

Process efficiency = (4390minute/5023minutes) * 100%

= 0.874*100%

= 87.4%

- **Future value stream mapping of FSR cargo**

It is better to model the new developed solution by constructing the future state of map selected products. The future state of map is mapped based on the new plant layout. Therefore the new FSR cargo fabrication process with the corresponding operational time and intended deadly wastes are expressed as below table 5.9.

Table 5.9. Average production time of FSR cargo by new plant layout.

s/no	Activity	Average Setup time in minute	Average operation time in minute	Average wasting time due to defect in minute	Average waiting time in minute	Average unnecessary inventory time in minute	Average movement waste time in minute
1	Issued material from main store				40	20	15
2	Material Preparation	10	480		25	15	10
3	Plate form preparation	10	240		10	5	5
4	Check Quality	5	10	15			
5	Floor sheet , front board, rear light and fixed bracket preparation	10	720		15	10	5
6	Side and rear board preparation	10	480		15	10	5
7	Check Quality	5	10	20			
8	Assemble side ,rear and front	10	480		15	10	5

	board						
9	Check Quality	5	10	10			
10	Washing and anti-rust painting	10	480		135	10	5
11	Check Quality	5	20	20			
12	Extension board preparation	10	720		15	10	5
13	Check Quality	5	10	20			
14	Assembly of extension board with half sponda	10	480		15	10	5
15	Preparation of all protection accessories	10	240		20	15	5
16	Check Quality	5	10	20			
17	Final painting	15	480		140	15	5
18	Assemble all accessories	10	240		15	10	5
19	Final check quality	5	10	15			
	Total	150	5120	120	460	140	75

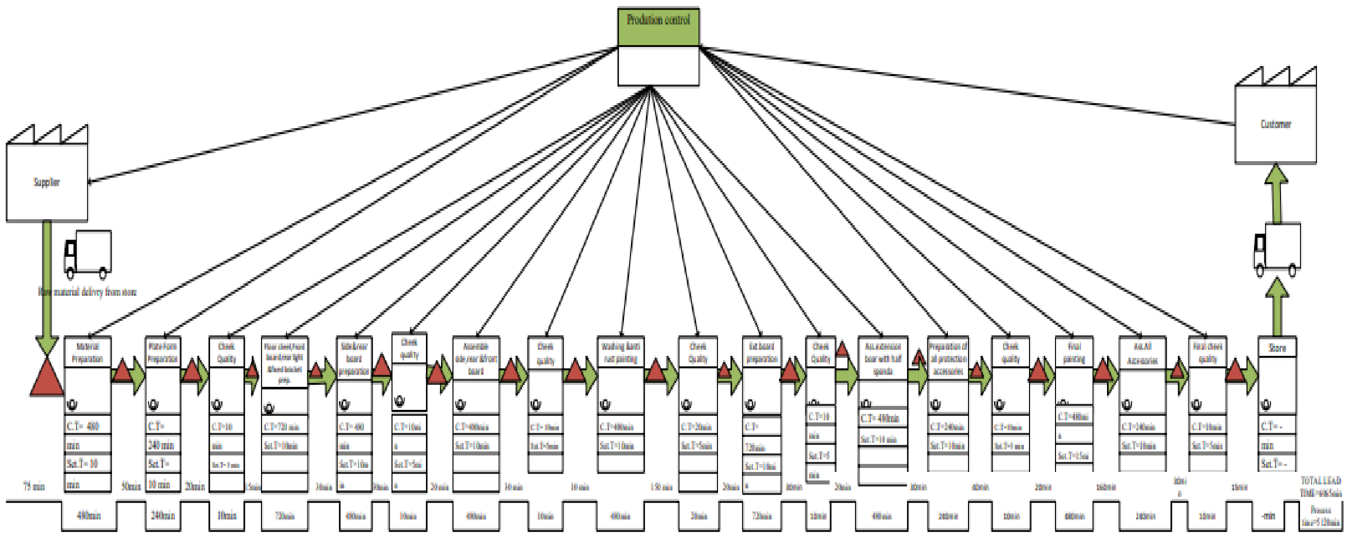

Figure 5.7. Future value stream map of FSR cargo.

As can see from figure 5.7 it describes about the future state map of FSR cargo fabrication process which is based on the new designed plant layout. From the map it was observed that the detail activities with the corresponding time taken. The total lead time was observed at the end of the process.

- **Takt time and process efficiency calculation after layout improvement**

Takt time is a calculation of the available production time divided by the customer demand. Whereas process efficiency is a calculation of the process time or operational time divided by the total lead time.

Takt time = available time/customer demand

Average customer demand per month is 12 units

Average Available time per month is 24 days or 192hrs

Takt time = 192hrs/12units = **16 hrs. Per unit product**

Process efficiency = (process time/lead time) * 100%

As can see from table 5.9: -

Total setup time = 150minute

Total process time = 5120 minute

Total wasting time due to defect = 120 minute

Total waiting time = 460minute

Total wasting time due to unnecessary inventory = 140minute

Total wasting time due to unnecessary movement = 75minue

So, total lead time = Total setup time + Total process time + Total wasting time due to defect + Total waiting time + Total wasting time due to unnecessary inventory + Total wasting time due to unnecessary movement

Total lead time = 150+5120+120+460+140+75 = **6065minute**

Total process time **= 5120minute**

Process efficiency = (5120minute/6065minute) * 100%

= 0.8441*100%

= 84.4%

- **Takt time and process efficiency calculation after layout improvement and applying oven on the painting process**

Currently the time required for painting is by 2 painters for washing and anti-rust painting is 9 hrs and for final painting is 12 hrs. But, among these 9 and 12 hrs operational time is 3 and 4hrs respectively and the other 6and 8 hrs respectively are required for drying. Then by using oven the drying time will reduced by 66 percent source (NA engineering practical experience).

Therefore, the waiting time is reduced by 66% and the process efficiency is calculated as follows.

Total setup time = 150minute

Total process time = 5120 minute

Total wasting time due to defect = 120 minute

Total waiting time = 156minute

Total wasting time due to unnecessary inventory = 140minute

Total wasting time due to unnecessary movement = 75minue

So, total lead time = Total setup time + Total process time + Total wasting time due to defect + Total waiting time + Total wasting time due to unnecessary inventory + Total wasting time due to unnecessary movement:

Total lead time = 150+5120+120+156+140+75 = **5761minute**

Total process time = **5120minute**

Process efficiency = (5120minute/5761minute) * 100%

= 0.888*100%

= 88.8%

- **Future value stream mapping of trailer**

It is better to model the new developed solution by constructing the future state of map selected products. The future state of map is mapped based on the new plant layout. Therefore the new FSR cargo fabrication process with the corresponding operational time and intended deadly wastes are expressed as below table 5.10

Table 5.10. Average production time of trailer by new plant layout.

s/no	Activity	Average Setup time in minute	Average operation time in minute	Average wasting time due to defect in minute	Average waiting time in minute	Average unnecessary inventory time in minute	Average movement waste time in minute
1	Issued material from main store				50	60	30
2	Material Preparation	20	960		75	40	35
3	Main chassis, frame and pocket with winch and hook preparation and welding and turning table tightening	10	960		40	20	10
4	Check Quality	5	15	30			
5	Platform and twist lock preparation and welding. Checkered	20	960		35	10	5

	welding						
6	Check Quality	5	30	20			
7	Axle and trolley preparation, assemble and welding	20	1440		45	10	15
8	Check Quality	5	40	30			
9	Side board, front board and board preparation and welding	25	1440		65	20	20
10	Check Quality	5	40	25			
11	Wheel carrier and fuel tank preparation and welding	15	960		35	15	15
12	Rear bumper, light guard, mud guard, copper key other accessories preparation and welding	20	480		55	20	15
13	Check Quality	5	20	50			
14	Connecting plate, draw bar preparation and welding	15	480		30	5	10
15	Check Quality	5	10	20			
16	Extension board preparation and welding	20	480		60	20	20
17	Check Quality	5	15	30			

18	Painting	30	2160		1680	20	15
19	check quality	5	50	60			
20	Electric line installation and compressed air tank installation	15	480		50	20	15
21	Assemble all accessary and extension board	20	480		70	30	20
22	Final check Quality	5	40	35			
	Total	275	11540	300	2290	290	225

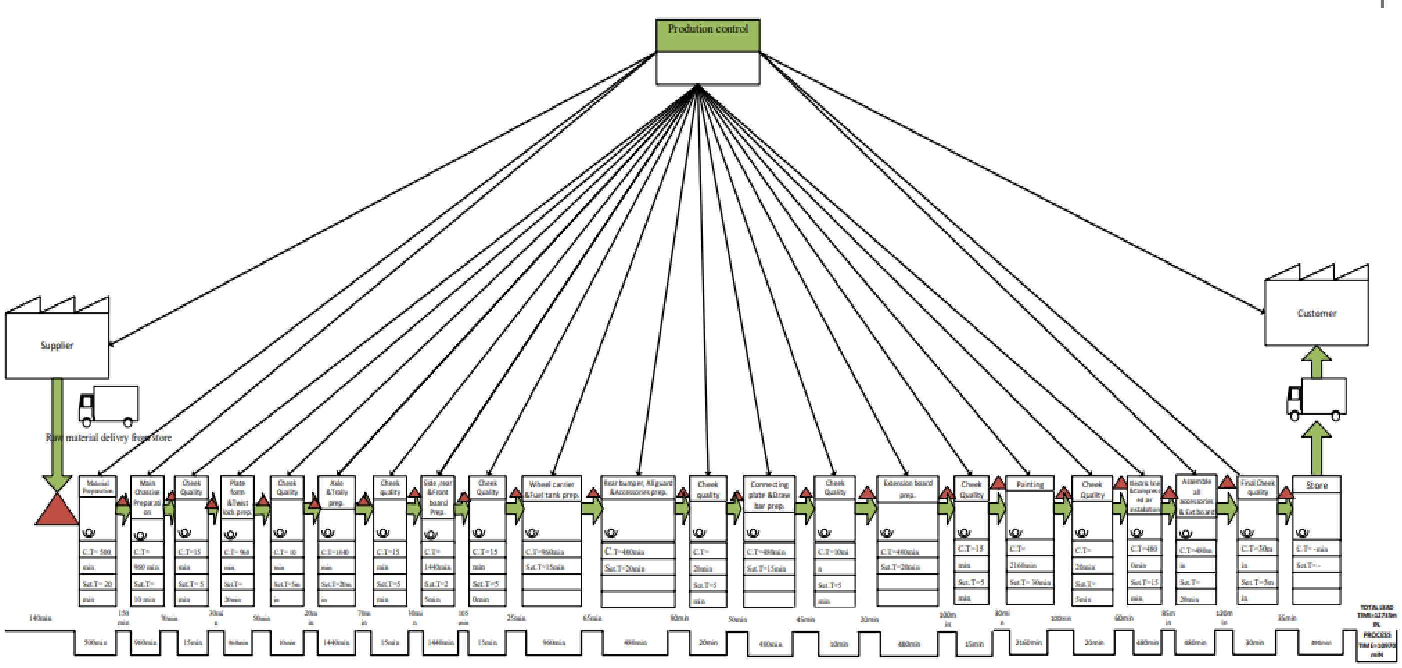

Figure 5.8. Future value stream map of trailer.

As can see from figure 5.8 it describes about the future state map of trailer fabrication process which is based on the new designed plant layout. From the map it was observed that the detail activities with the corresponding time taken. The total lead time was observed at the end of the process.

- **Takt time and process efficiency calculation after layout improvement**

Takt time is a calculation of the available production time divided by the customer demand. Whereas process efficiency is a calculation of the process time or operational time divided by the total lead time.

Takt time = available time/customer demand

Average customer demand per month is 5 units

Average Available time per month is 24 days or 192hrs

Takt time = 192hrs/5units = **38.4 hrs. Per unit product**

Process efficiency = (process time/lead time) * 100%

As can see from table 5.10: -

Total setup time = 275minute

Total process time = 11540 minute

Total wasting time due to defect = 300 minute

Total waiting time = 2290minute

Total wasting time due to unnecessary inventory = 290minute

Total wasting time due to unnecessary movement = 225minute

So, total lead time = Total setup time + Total process time + Total wasting time due to defect + Total waiting time + Total wasting time due to unnecessary inventory + Total wasting time due to unnecessary movement

Total lead time = 275+11540+300+2290+290+225 = **14920minute**

Total process time **= 11540minute**

Process efficiency = (11540minute/14920minute) * 100%

= 0.773*100%

= 77.3%

- **Takt time and process efficiency calculation after layout improvement and applying oven at the painting process and used simple press machine at the axle preparation process.**

Currently the time required for painting is by 2 painters for painting is 35 hrs and by 3 welders for axle preparation is 13 hrs. But, among these 35 hrs only 12 hrs is operational and the 23 hrs are needs for drying and for axle preparation among these 13 hrs 30 percent are consumed by fitting the hallow pipe. Then by using oven the drying time is reduced by 66 percent and axle preparation time is reduced by 4 hrs by using simple press machine for hallow pipe. Using this machine is reduced the fitting process time by 75 percent source (NA engineering practical experience and mulualem carasory).

Therefore, the waiting time is reduced by 66% and total process time is reduced by 240 minute or 4 hrs then the process efficiency is calculated as follows.

Total setup time = 275minute

Total process time = 11300 minute

Total wasting time due to defect = 300 minute

Total waiting time = 778minute

Total wasting time due to unnecessary inventory = 290minute

Total wasting time due to unnecessary movement = 225minute

So, total lead time = Total setup time + Total process time + Total wasting time due to defect + Total waiting time + Total wasting time due to unnecessary inventory + Total wasting time due to unnecessary movement

Total lead time = 275+11300+300+778+290+225 = **13168minute**

Total process time **= 11300minute**

Process efficiency = (11300minute/13168minute) * 100%

= 0.858*100%

= 85.8%

5.2. Validation

The final result of this paper is designing the plant layout that can enhance the operational performance of the case company. Doing an experimental validation of the manufacturing process is a time and budget consuming process. Therefore, the result validation is performed by using simulation software which is called arena. Before going to simulate the newly designed solution it is better to simulate the existing working condition as it is and that is good to see the difference and proof the improvement.

5.2.1. Simulation of existing model

➢ **Existing model of NPR van**

Assumptions:

In order to model the process, we needed to have the following assumptions.

1. From each process there are two welders and for the matter of modeling let's assume two welders have equal capacity.
2. Each data is collected from the company document and we trust it.
3. There are three painters and those painters also have equal capacity.
4. There are two material preparation operators and those operators also have the same capacity.

The data was collected from the beginning up to the end of the process of NPR van production. The sample size is equal for all activities because all these activities are performed on one product. List of activities with the corresponding sample size are explain as follows.

Table 5.11. List of activities with corresponding sample size.

S/No	Process description	Sample size	remark
1	Material preparation	10	
2	Plat form preparation	10	
3	Plat form anti-rust painting	10	
4	Floor sheet covering	10	
5	Mainframe preparation	10	

6	Side, front, rear and roof sheet covering	10	
7	Side and rear bumper preparation	10	
8	Side and rear door preparation	10	
9	All accessary preparation	10	
10	Washing and painting	10	
11	Aluminum sheet covering	10	
12	Side and rear door lock & J-rubber fitting	10	
13	Accessary fitting	10	

5.2.2. Input modeling system of existing NPR van

Each set of data points representing a distribution of cutting, bending, welding and painting process or inter-arrival times were analyzed using arena input analyzer in order to fit a general distribution. The data were directly collected and by using Microsoft excel and this data were enter to the arena input analyzer and the following distribution will achieve.

Table 5.12. List of activities of existing production process of NPR van with compatible distribution.

S/No	Activity description	Compatible distribution	remark
1	Job inter-arrival rate	Unif (95.5, 121)	
2	Material preparation	Unif (11,15)	
3	Plat form preparation	Unif (3.5,4.5)	
4	Plat form anti-rust painting	Unif (2.5, 3.5)	
5	Floor sheet covering	Unif (3, 4.5)	
6	Mainframe preparation	Tria (5,7,9)	
7	Side, front, rear and roof sheet covering	Tria (15,17,19)	
8	Side and rear bumper preparation	Tria (7,8,9)	
9	Side and rear door preparation	Tria (6,7,8)	
10	All accessary preparation	Nor (6.6, 0.539)	
11	Washing and painting	Unif (20, 24)	
12	Aluminum sheet covering	Unif (8,10)	

13	Side and rear door lock & J-rubber fitting	Unif (4,6)	
14	Accessary fitting	Tria (6,8,10)	

The above table 5.12 describes the list of activities NPR van fabrication process with compatible distribution. Compatible distribution means when the input data were analyzed by using input analyzer the distribution with minimum error was consider as a compatible distribution.

Now by using the above parameters the current NPR van production process is simulated as follows. During simulation by assuming that there are two welders, three painters, three material preparation operators and one accessary fitting operator. And the very important part is the recorded data of quality which means how much percent are go back for rework and how much percent are go directly to the next station. So, these percentages are calculated from quality control department check sheet data. And the measurement unit of time for all activity is hour. So, as per this information the model is doing as follows.

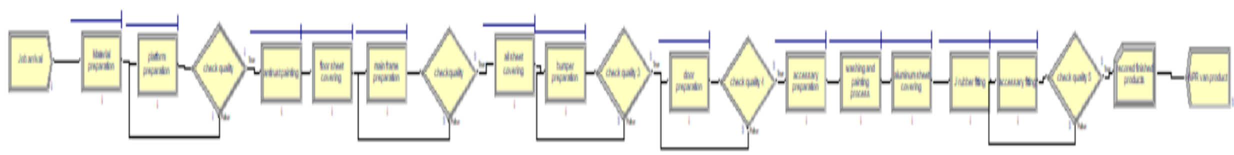

Figure 5.9. Simulation diagram of existing production process of NPR van.

Figure 5.9 shows the diagram of simulation process of existing fabrication process of NPR van from the simulation the detail required date were mansion including: number or resource, amount of time with compatible distribution, the nature the process and others.

➢ **Result of the existing production process simulation of NPR van**

The output of the modeling is explained as follows the simulation is run for 1000 hrs. And the time base is hrs. And also hrs. Per day is 8 which bases from the case company way of working. Means the case company works 8 hours per day. So, the general output is: -

- The average waiting time was 28.17hrs.
- The total time that the product at the system was 130 hrs.
- Utilization of painter 1, 2 & was 22.24%

- Utilization of welder 1 & 2 iswas5%
- Utilization of material preparation operator was 11.58%
- The number of finished products of NPR van with 1000 hours were 8 units.
- The number of works in progress units were 1.35

5.2.3. Input modeling system of existing FSR cargo

Each set of data points representing a distribution of cutting, bending, welding and painting process or inter-arrival times were analyzed using arena input analyzer in order to fit a general distribution. The data are directly collected and by using microsoft excel and this data are entering to the arena input analyzer and the following distribution will achieve.

Table 5.13. List of activities of existing production process of FSR cargo with compatible distribution.

S/No	Activity description	Compatible distribution	remark
1	Job inter-arrival rate	Nor (124,6.8)	
2	Material preparation	Nor (11.9,0.624)	
3	Platform preparation	Unif (3,4.66)	
4	Floor sheet covering	Unif (2.4,3.6)	
5	Front board preparation	Tria (2.4,2.52,3.6)	
6	Side and rear board preparation	Tria (5.3,6.5,7.7)	
7	Fixed bracket preparation	Unif (2,2.55)	
8	Rear light protector preparation	Unif (2.4,3.6)	
9	Half sponda accessary preparation	Tria (4,4.5,5)	
10	Assemble half sponda with front board	Tria (4,4.5,5)	
11	Washing and anti-rust painting of half sponda	Tria (8,8.06,9.65)	
12	Extension board preparation	Tria (6,6.27,7.65)	
13	Extension board anti-rust painting	Tria (1.25,1.38,3)	
14	Extension board accessary preparation	Unif (3.4, 4.6)	
15	Assemble extension board with half sponda	Tria (6, 6.27, 7.65)	

16	Final painting	Unif (18.5,24.5),	
17	Accessary fitting	Nor (8.33,0.434)	

The above table 5.13 describes the list of activities FSR cargo fabrication process with compatible distribution. Compatible distribution means when the input data were analyzed by using input analyzer the distribution with minimum error was consider as a compatible distribution.

Now by using the above parameters the current FSR cargo production process is simulated as follows. During simulation by assuming that there are two welders, three painters, three material preparation operators and one accessary fitting operator. And the very important part is the recorded data of quality which means how much percent are go back for rework and how much percent are go directly to the next station. So, these percentages are calculated from quality control department check sheet data. And the measurement unit of time for all activity is hour. So, as per this information the model is doing as follows.

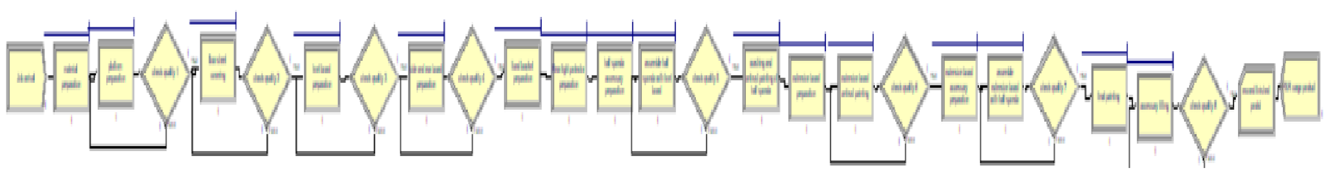

Figure 5.10. Simulation diagram of existing production process of FSR cargo.

Figure 5.10 shows the diagram of simulation process of existing fabrication process of FSR cargo. From the simulation the detail required date were mansion including: number or resource, amount of time with compatible distribution, the nature the process and others.

- **Result of the existing production process simulation of FSR cargo**

The output of the modeling is explained as follows the simulation is run for 1000 hrs. And the time base is hrs. And also hrs. Per day is 8 which bases from the case company way of working. Means the case company works 8 hours per day. So, the general output is: -

- The average waiting time was 40 hrs.
- The total time that the product at the system is 158 hrs.
- Utilization of painter 1, 2 & 3 was 20%
- Utilization of welder 1 & 2 was 45%

- Utilization of material preparation operator was 8.3%
- The number of finished products of NPR van with 1000 hours were 6 units.
- The number of works in progress units was 1unit

5.2.4. Input modeling system of existing Trailer

Each set of data points representing a distribution of cutting, bending, welding and painting process or inter-arrival times were analyzed using arena input analyzer in order to fit a general distribution. The data are directly collected and by using Microsoft excel and this data are entered to the arena input analyzer and the following distribution will achieve.

Table 5.14. List of activities of existing production process of trailer with compatible distribution.

S/No	Activity description	Compatible distribution	remark
1	Job inter-arrival rate	Unif (200, 225)	
2	Material preparation	Unif (19.5, 24.5)	
3	Chassis preparation	Nor (6.64, 0.699	
4	Trolley preparation	Unif (4, 5)	
5	Frame preparation	Unif (5. 6)	
6	Suspension plate preparation	Tria (3, 4.16, 5)	
7	Axel preparation	Tria (22, 24, 26)	
8	Turning table preparation	Unif (3.62, 5)	
9	Omega preparation	Nor (6.64, 0.699)	
10	Floor sheet covering	Unif (4, 6)	
11	Board preparation	Tria (9.5,12.3, 14.5)	
12	Wheel carrier preparation	Unif (6,8)	
13	Fuel talk preparation	Tria (4, 4.16, 5.65)	
14	Connecting plate preparation	Unif (6, 7.65)	
15	All accessary preparation	Tria (4, 5.48, 5.65)	
16	Mud guard preparation	Nor (6.72, 0.579)	
17	Extension board preparation	Nor (11.7, 0.87)	
18	Washing and painting	Uniform (51, 54)	
19	Electric line installation	Nor (6.65, 0.699)	

20	Accessary fitting	Unif (8.25, 11)	

The above table 5.14 describes the list of activities trailer fabrication process with compatible distribution. Compatible distribution means when the input data were analyzed by using input analyzer the distribution with minimum error was consider as a compatible distribution.

Now by using the above parameters the current Trailer production process is simulated as follows. During simulation by assuming that there are three welders, three painters, three material preparation operators. And the very important part is the recorded data of quality which means how much percent are go back for rework and how much percent are go directly to the next station. So, these percentages are calculated from quality control department check sheet data. Then the input data are explained as follows. And the measurement unit of time for all activity is hour. So, as per this information the model is doing as follows.

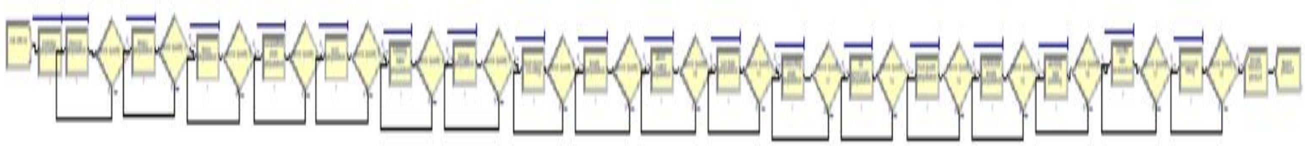

Figure 5.11. Simulation diagram of newly existing production process of trailer.

Figure 5.11 shows the diagram of simulation process of existing fabrication process of trailer. From the simulation the detail required date were mansion including: number or resource, amount of time with compatible distribution, the nature the process and others.

- **Result of the existing production process simulation of Trailer**

The output of the modeling is explained as follows the simulation is run for 1000 hrs. And the time base is hrs. And also hrs. Per day is 8 which bases from the case company way of working. Means the case company works 8 hours per day. So, the general output is: -

- The average waiting time was 146 hrs.
- The total time that the product at the system was 275 hrs.
- Utilization of painter 1, 2 & 3 was 15.5%
- Utilization of welder 1 & 2 was 91%
- Utilization of material preparation operator was 17%
- Utilization of electrician 1, 2 & was 2%

- The number of finished products of NPR van with 1000 hours were 3 units.
- The number of works in progress units were 3.3unit

5.3. Simulation of new developed model by improving only the plant layout

Each set of data points representing a distribution of cutting, bending, welding and painting process or inter-arrival times were analyzed using arena input analyzer in order to fit a general distribution. The data are directly collected and by using Microsoft excel from the current operation and this data are enter to the arena input analyzer and the following distribution will achieve.

5.3.1. Simulation of new developed model for NPR van

Table 5.15. List of activities of new developed production process of NPR van with compatible distribution.

S/No	Activity Distribution	Compatible distribution	Remark
1	Job inter-arrival rate	Unif (13,14)	
2	Material preparation	Unif (4.4, 5.6)	
3	Plat form and main frame preparation and floor sheet covering	Unif (4,5)	
4	Side, rear and roof sheet covering	Tria (4,.5,5)	
5	Preparation of rear and side door	Tria (4,4.5,5)	
6	Side and rear bumper and fender preparation	Tria (4,4.5,5)	
7	Accessary preparation	Tria (4,4.5,5)	
8	Washing and painting	Unif (10,12)	
9	Aluminum sheet covering	Tria (4,4.5,5)	

10	Accessary fitting	Tria (4,4.5,5)	

The above table 5.15 describes the list of activities NPR van fabrication process based on new plant layout with compatible distribution. Compatible distribution means when the input data were analyzed by using input analyzer the distribution with minimum error was consider as a compatible distribution.

Now by using the above parameters the future NPR van production process is simulated as follows. During simulation by assuming that there are 13 welders, 3 painters, 3 material preparation operators and 1 accessary fitting operator. And the very important part is the recorded data of quality which means how much percent are go back for rework and how much percent are go directly to the next station. So, these percentages are estimated by assuming during the layout improvement the quality of work will be improved. And the measurement unit of time for all activity is hour. So, as per this information the model is doing as follows:

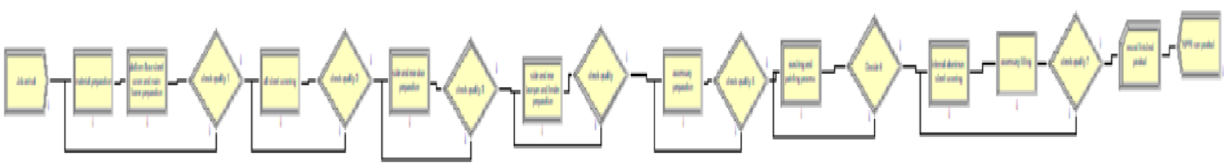

Figure 5.12. Simulation diagram of newly developed production process of NPR van.

Figure 5.12 shows the diagram of simulation process of fabrication process of NPR van based on new designed plant layout. From the simulation the detail required date were mansion including: number or resource, amount of time with compatible distribution, the nature the process and others.

- **Result of the new developed production process simulation of NPR van**

The output of the modeling is explained as follows the simulation is run for 1000 hrs. And the time base is hrs. And also hrs. Per day is 8 which bases from the case company way of working. Means the case company works 8 hours per day. So, the general output is: -

- The average waiting time was 6hrs.
- The total time that the product at the system was 53 hrs.

- Utilization of painter 1, 2 & was 45%
- Utilization of welder 1 & 2 was 90%
- Utilization of material preparation operator was 40%
- The number of finished products of NPR van with 1000 hours were 60 units.
- The number of works in progress units were 22 units

5.3.2. Simulation of new developed model for FSR cargo

Table 5.16. List of activities of new developed production process of FSR cargo with compatible distribution.

S/No	Activity Description	Compatible distribution	Remark
1	Job inter-arrival rate	Unif (11,13)	
2	Material preparation	Unif (4,4.55)	
3	Platform preparation	Unif (4,4.5)	
4	Floor sheet covering, front board, rear light protector and fixed bracket preparation	Tria (4,4.05,4.55)	
5	Side and rear board preparation	Unif (4.4.55)	
6	Assemble side and rear board with front board	Tria (4,4.05,4.55)	
7	Washing and anti-rust painting	Unif (7,9)	
8	Extension board preparation	Unif (5.35,7)	
9	Assemble half sponda with extension board	Tria (4,4.05,4.55)	
10	Accessary preparation	Unif (4,4.55)	
11	Final painting	Unif (10,12)	
12	Accessary fitting	Unif (4,4.5)	

The above table 5.16 describes the list of activities FSR cargo fabrication process based on new plant layout with compatible distribution. Compatible distribution means when the input data were analyzed by using input analyzer the distribution with minimum error was consider as a compatible distribution.

Now by using the above parameters the future FSR cargo production process is simulated as follows. During simulation by assuming that there are 11 welders, 4 painters, 2 material preparation operators and 1 accessary fitting operator. And the very important part is the recorded data of quality which means how much percent are go back for rework and how much percent are go directly to the next station. So, these percentages are estimated by assuming that quality of work will improve if the layout improved. And the measurement unit of time for all activity is hour. So, as per this information the model is doing as follows.

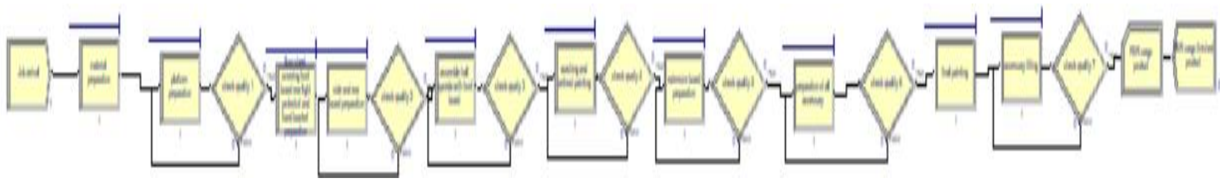

Figure 5.13. Simulation diagram of newly developed production process of FSR cargo.

Figure 5.13 shows the diagram of simulation process of fabrication process of FSR cargo based on new designed plant layout. From the simulation the detail required date were mansion including: number or resource, amount of time with compatible distribution, the nature the process and others.

➢ **Result of the new developed production process simulation of FSR cargo**

The output of the modeling is explained as follows the simulation is run for 1000 hrs. And the time base is hrs. And also hrs. Per day is 8 which bases from the case company way of working. Means the case company works 8 hours per day. So, the general output is: -

- The average waiting time was 7hrs.
- The total time that the product at the system was 68 hrs.
- Utilization of painter 1, 2 & 3 was 55%
- Utilization of welder 1 & 2 was 90%
- Utilization of material preparation operator was 40%
- The number of finished products of FSR cargo with 1000 hours were 45 units.
- The number of works in progress units were 35 unit

5.3.3. Simulation of new developed model for Trailer

Table 5.17. List of activities of new developed production process of trailer with compatible distribution.

S/No	Description of Activities	Compatible distribution	Remark
1	Job inter-arrival rate	Tria (31,32,34)	
2	Material preparation (cutting and bending)	Unif (8,9)	
3	Main chassis, frame, winch, hook & turning table preparation	Unif (8,9)	
4	Platform and twist lock preparation and floor sheet covering	Tria (8,8.1,9)	
5	Axle and trolley preparation	Nor (12.2, 0.594)	
6	Side, rear & front board preparation	Tria (8,8.1,9)	
7	Wheel carrier and fuel tank preparation	Tria (8,8.1,9)	
8	Rear bumper, mud guard, light guard, copper key supper & other accessary preparation	Tria (8,8.1,9),	
9	Connecting plate & draw bar preparation	Tria (8,8.1,9)	
10	Extension board preparation	Tria (8,8.1,9	
11	Washing & painting	Tria (30.5,32,35.5)	
12	Electric line and compressed air tank installation	Tria (8,8.1,9)	
13	Accessary and extension board assembly	Tria (7,8.15,8.65)	

The above table 5.17 describes the list of activities trailer fabrication process based on new plant layout with compatible distribution. Compatible distribution means when the input data were analyzed by using input analyzer the distribution with minimum error was consider as a compatible distribution.

Now by using the above parameters the future Trailer production process is simulated as follows. During simulation by assuming that there are 17 welders, 2 painters, 2 material preparation operators. And the very important part is the recorded data of quality which means how much percent are go back for rework and how much percent are go directly to the next station. So, these percentages are estimated by assuming the quality of work will be improved. And the measurement unit of time for all activity is hour. So, as per this information the model is doing as follows.

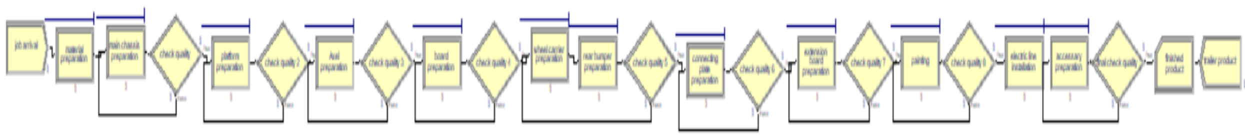

Figure 5.14. Simulation diagram of newly developed production process of trailer.

Figure 5.14 shows the diagram of simulation process of fabrication process of trailer based on new designed plant layout. From the simulation the detail required date were mansion including: number or resource, amount of time with compatible distribution, the nature the process and others.

➢ **Result of the new developed production process simulation of Trailer**

The output of the modeling is explained as follows the simulation is run for 1000 hrs. And the time base is hrs. And also hrs. Per day is 8 which bases from the case company way of working. Means the case company works 8 hours per day. So, the general output is: -

- The average waiting time was 12 hrs.
- The total time that the product at the system was 137 hrs.
- Utilization of painter 1, 2 & was 28%
- Utilization of welder 1 & 2 was 94%
- Utilization of material preparation operator was 26%
- Utilization of electrician 1, 2 & was 7%
- The number of finished products of trailer with 1000 hours were 16 units.
- The number of works in progress units were 15 unit

5.3.4. Simulation of new developed model in addition to the plant layout by improving painting process and using simple press machine.

As can see from the evaluation process it is understandable that one of the main bottle neck processes from each product type is painting process and the reason why this process takes a large time is because it needs a lot of time for drying. In order solve problem and improve the performance it is better to use oven machine that can reduce the time for drying and also improve the quality of painting. In addition to this from the fabrication process of trailer there is one process called axle preparation and this process takes a large time and be a bottle neck in the process. So, in order to solve this problem and improve the performance it is better to use simple press machine in this specific process.

5.3.5. Simulation of new developed model in addition to the plant layout by improving painting process for NPR van.

As can see from the result of new developed mode simulation there is an average waiting time of 6 hrs which comes due the painting process. One of the main reasons why painting process become a bottle neck is because it needs a large time to dry. Now this bottle neck can be reduced by using oven for the fast drying.

Note the process are the same as listed at table 5.15 the only variation is that the time taken to the painting process and the inter-arrival rate.

Currently the time required for painting is by three painters is 12 hrs. But, among these 12 hrs operational time is 3 hrs and the other 9 hrs are required for drying. Then by using oven the drying time will reduced by 66 percent source (NA engineering practical experience).

Therefore, the simulation results are shown as follows:

The output of the modeling is explained as follows the simulation is run for 1000 hrs. And the time base is hrs. And also hrs. Per day is 8 which bases from the case company way of working. Means the case company works 8 hours per day. So, the general output is: -

- The average waiting time was 2 hrs.
- The total time that the product at the system was 46.5 hrs.

- Utilization of painter 1, 2 & was 75%
- Utilization of welder 1 & 2 was 95%
- Utilization of material preparation operator was 60%
- The number of finished products of NPR van with 1000 hours were 100 units.
- The number of works in progress units were 15 units

5.3.6. Simulation of new developed model in addition to the plant layout by improving painting process for FSR cargo.

As can see from the result of new developed mode simulation there is an average waiting time of 7 hrs which comes due the painting process. One of the main reasons why painting process become a bottle neck is because it needs a large time to dry. Now this bottle neck can be reduced by using oven for the fast drying.

Note the process are the same as listed at table 5.16 the only variation is that the time taken to the washing and anti-rust painting, painting process and the inter-arrival rate.

Currently the time required for painting is by 2 painters for washing and anti-rust painting is 9 hrs and for final painting is 12 hrs. But, among these 9 and 12 hrs operational time is 3 and 4hrs respectively and the other 6and 8 hrs respectively are required for drying. Then by using oven the drying time will reduced by 66 percent source (NA engineering practical experience).

Therefore, the simulation results are shown as follows:

The output of the modeling is explained as follows the simulation is run for 1000 hrs. And the time base is hrs. And also hrs. Per day is 8 which bases from the case company way of working. Means the case company works 8 hours per day. So, the general output is: -

- The average waiting time was 3hrs.
- The total time that the product at the system was 52.5 hrs.
- Utilization of painter 1, 2 & 3 was 80%
- Utilization of welder 1 & 2 was 95%
- Utilization of material preparation operator was 70%
- The number of finished products of FSR cargo with 1000 hours were 85 units.
- The number of works in progress units were 25 unit

5.3.7. Simulation of new developed model in addition to the plant layout by improving painting process axle preparation process for Trailer.

As can see from the result of new developed mode simulation there is an average waiting time of 12 hrs which comes due the painting and axle preparation process. One of the main reasons why painting process become a bottle neck is because it needs a large time to dry and axle preparation is due the process nature. Now this bottle neck can be reduced by using oven for the fast drying and using simple press machine for axe preparation process.

Note the process are the same as listed at table 5.17 the only variation is that the time taken to the axle preparation, painting process and the inter-arrival rate.

Currently the time required for painting is by 2 painters for painting is 35 hrs and by 3 welders for axle preparation is 13 hrs. But, among these 35 hrs only 12 hrs is operational and the 23 hrs are needs for drying and for axle preparation among these 13 hrs 30 percent are consumed by fitting the hallow pipe. Then by using oven the drying time will reduced by 66 percent and axle preparation time is reduced by 4 hrs by using simple press machine for hallow pipe. Using this machine is reduced the fitting process time by 75 percent source (NA engineering practical experience and mulualem carasory).

Therefore, the simulation results are shown as follows:

The output of the modeling is explained as follows the simulation is run for 1000 hrs. And the time base is hrs. And also hrs. Per day is 8 which bases from the case company way of working. Means the case company works 8 hours per day. So, the general output is: -

- The average waiting time was 5 hrs.
- The total time that the product at the system was 117 hrs.
- Utilization of painter 1, 2 & was 75%
- Utilization of welder 1 & 2 was 96%
- Utilization of material preparation operator was 60%
- Utilization of electrician 1, 2 & was 25%
- The number of finished products of trailer with 1000 hours were 35 units.
- The number of works in progress units were 10 unit

5.4. Result and Discussion

This paper is working on assessment and evaluation of performance of metal fabrication factory for metal cargo body and trailer fabrication. The assessment and evaluation process are performed on three major product types like: NPR van, FSR cargo, and trailer. The assessment and evaluation process are performed by using value stream mapping method and from the process evaluation the following major wastes are identified these are: - waiting time, large set-up time, unnecessary inventory, unnecessary movement and defect. Then by using cause and effect diagram the root cause for these wastes and these are: - poor plant lay out, unbalanced work process, variety of activities in a single station, availability of unnecessary satellite store, shortage of auxiliary tools and equipment's and workers skill gap.

The current process efficiency of the case company is calculated by using these three product types and the result is for NPR van the process efficiency is 62%, for FSR cargo is 56.9% and for trailer is 55.38%.

Questioner survey also conducted in the case company to identify the root cause for low operational performance with the highest weight. Then poor plat layout is the major root cause with the score of reliability test of cronbach's alpha value of 0.918, descriptive analysis the mean value is 4.18 and pearson's correlation r-0.718.

Based on the evaluation result the appropriate solution is developed that can enhance the operational performance. The major solution developed is design new plant layout and during the design process systematic layout planning model and future state of value stream mapping methods are used. So, the current layout type is fixed position layout and new designed layout is product layout type. This new design layout is significantly reducing those identified wastes and improve the process efficiency of each product mix production process. For example, the process efficiency of NPR van is increase from 62% to 80.74%, FSR cargo is increase from 56.9% to 84.4% and trailer is increase from 53.38% to 77.3%. However, only design new plant layout cannot reduce the waiting time of painting process from each product mix. Therefore, using oven machine is better to reduce the waiting time to dry and also improve the quality painting. In addition to this on the production process of trailer there is axle preparation process which needs more time so it is better to use simple press machine and can enhance the process efficiency. By doing these improvements the process efficiency of each product also increase example the process efficiency of NPR van is increase from 80.74% to 87.4%, FSR cargo is increase from 84.4% to 88.8% and trailer is increase from 77.3% to 85.8%.

Generally, the new developed solution brings a significant operational performance enhancement of each product mix. For example, for NPR van production process there is 25.4% efficiency increment, for FSR cargo production process there is 31.9% efficiency improvement and for trailer production process there is 32.42% efficiency increment.

Finally, the research result is validated by simulation using simulation software called arena. The simulation is conducted three times 1, the existing working process, 2, after design of new plant layout and 3, after applying oven and simple press machine. From the simulation result it is observed that a large reduction of waiting time, the large increment of throughput and also a significant improvement of instant utilization of welders, painters and material preparation operators.

Chapter Six

6. Conclusion and Recommendation

6.1. Conclusion

Industry operational performance assessment and evaluation can be used as the foundation for evaluating how a range of possible actions will impact profitability. The performance analysis measurement provides to, sustain or modifying the process or procedure to increase the output, increase efficiency, or increase the effectiveness of the process or procedure.

This paper was working on selecting the appropriate performance measurement parameters or key performance indicator (KPI) of the manufacturing companies and performing assessment, evaluation and enhancement of operational performance of metal fabrication factory of metal cargo body and trailer fabrication a case of kaki plc. The assessment and evaluation were conducted by selecting three major product type of the case company namely: - NPR van, FSR cargo and trailer then using various methods like: - value stream mapping, cause and effect diagram and also questioner survey the evaluation process is performed. Then by finding the causes for low operational performance of the case company which were: - waiting time, defect, large set-up time, unnecessary inventory, and unnecessary movement. Then from the questioner survey among various root causes the main root cause is identified. Then based on the summary of finding proceed to working on developing the solution for the identified problem. The solution developed was design new product layout for these three major products and applying other solutions like using oven in painting process in all production process and using simple press machine in trailer production process.

Finally, the developed solution brings a significant improvement of production process efficiency of each product mix for example the production process efficiency of NPR van increase from 62% to 87.4%, the production process efficiency of FSR cargo increase from 56.9% to 88.8% and the production process efficiency of trailer increase from 53.38 to 85.8%. These improvements were a remarkable improvement and validated by simulation using software called arena and from the simulation it is also observed a significant process improvement, waiting time reduction and throughput increment.

6.2. Recommendation

Based the above study conclusion there are some recommendation needs to consider by the case company (KAKI plc.).

- Productivity is the basic for the survival and competitiveness of the manufacturing industries in all aspects. Therefore, companies have to manage their resources effectively to have efficient manufacturing system and develop sustainable growth.
- Kaki plc. Has a problem with productivity and operational performance. And this research is working on detail analysis of the manufacturing of process of the case company and identify the major wastes with their root causes. Then following the result, the better solution is developed.
- Currently the case company is following in efficient way of manufacturing process. Therefore, it is better to implement this model for maximum out with minimum waste.
- Generally, manufacturing industries are required a continuous improvement and lean practice is the better solution to implement continuous improvement and reduce wastes.

6.3. Future work

This study was focused on the case company (Kaki plc.) to improve the operational performance using lean practice. For the future proceeding from this it is better to working on other principles of optimization for efficient manufacturing system of the industries.

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Annex A

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KAKI PRIVATE LIMITED COMPANY

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INTERNAL MEMORANDUM

- **ለ** ምርት ዋና ክፍል
- **ከ** ሽያጭ መምሪያ
- **ቀን** 04/04/2015

ጉዳዩ፡- የተሽከርካሪዎች የቦዲ ስራ ርክክብን ይመለከታል፤

እንደሚታወቀው በድርጅታችን ውስጥ ለሽያጭ ለምናቀርባቸው ተሽከርካሪዎች የቦዲ ስራ የምንሰራ መሆኑ ይታወሳል፡፡

ሆኖም ከምርት ክፍል የሚሰጠንን የማስረከቢያ ጊዜ ስሌዳ በመጠቀም ተሽከርካሪዎችን የምንሸጥ ቢሆንም በተሰጠው ጊዜ ምርቶቹን ማስረከብ ባለመቻላችን ደንበኞቻችንን እያሳዘንን ያለ መሆኑን እናንተም ትረዳላችሁ፡፡

በመሆኑም የምርት ክፍሉም ይህንን በማጤን እና የምርት ማስረከቢያ ጊዜውን ማስተካከል እንዳለበት በመረዳት እና ደንበኞቻችን በሚያኙት አገልግሎት ተደስተው እንዲሄዱ የበኩላችሁን ጥረት በማድረግ ለድርጅቱ እንዲሁም ለሽያጭ መምሪያው ጥረት ስኬት የናንተም ሚና ወሳኝ በመሆኑ አስቸኳይ እና ትክክለኛ የሆነ የማስረከቢያ ጊዜ ክለሳ አድርጋችሁ እንደትልኩልን በአክብሮት እየጠየቅን ይህ ካልሆነ ግን ተሽከርካሪዎቹን ወደ ሌላ ጋራዥ ልከን ለማሰራት የምንገደድ መሆኑን እንገልፃለን፡፡

ከሠላምታ ጋር

ግልባጭ፡

- ለዋና ሥራ አስኪያጅ
- ለማኔጂንግ ዳይሬክተር
- ለፕሮግራም ሥራ አስኪያጅ
- ለማርኬቲንግ መምሪያ
- ለኳሊቲ ንትሮል
- ለንብረት አስተዳደር

Annex B

Addis Ababa University

Addis Ababa Institute of Technology (AAiT)

School of Mechanical and Industrial Engineering

Graduate Program in Manufacturing Engineering

Survey Questionnaire: on operational performance of metal cargo body and trailer fabrication a case of KAKI PLC

Prepared by: Lewutie Edmealem

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Advisor: Dr. Desalegn Wogaso

Thesis Title: Assessment, evaluation and enhancement of operational performance of metal fabrication workshop for cargo body and trailer fabrication through lean practice.

A case of KAKI PLC

The objective of the questionnaire is to assess the root cause for the low operational performance of metal cargo body and trailer fabrication process of the case company. Once identify the root it is easy for improvement and will go for necessary step for improvement.

Hereby, I would like to be express my gratefulness for your committed cooperation to answer this attached questionnaire. And all the questions are well designed for quick and easy response.

Finally, this questionnaire is conducted for Msc. Thesis, hence I promise you that the information you get from this questionnaire will be revised confidential and will not be transferred to other parties for any other purpose. If you need further clarification, please contact me at the above email address.

Survey Questionnaire

I. Respondent Information

a) Gender: ________Male ____________Female

b) Current Position in the company_____________________________________.

c) Qualification____________________1 = Diploma; 2=BSc /BA;3=MSc/MA;4=PhD; 5=Others(Specify)

d) Field of specialization______________________________

e) Work experience in this or other related company (in years) ________________.

II. Company Profile

a) Name of the company__________________________

b) Ownership of the company:1=private; 2=public;3=private & public________________

c) Total number of employees_________________

d) Number of working time per shift___________________

III. Questions given to the respondents

Section 01: Assessment of production plant layout of the case company		Score				
		1	2	3	4	5
1	The plant layout of the company is convienent for production process?					
2	The current layout of the company is operationaly effiecient					
3	The current layout of the company is siutable for workrs saftey and product quality					
4	Each product item of the case company has their own production layout					

Section 02: Assesment of un-balanced work process of the case company		Score				
		1	2	3	4	5
1	The fabrication process of case company has proper line balancing					
2	The line balancing of the fabrication process has no effect on quality of the product					
3	The line balancing of the fabrication process has no effect on the efficiency of the operation					

Section 03: Assesment of variaty of activity in a single station in th production process of the case company		Score				
		1	2	3	4	5
1	Variaty of activity in a single station has no effect on the quality of the product					
2	Variaty of activity in a single station has no effect on effieciency of the operation					
3	Variaty of activity in a single station is convienent for technicians					

Section 04: Assesment of un-necessary satellite store for processed material in the case company		Score				
		1	2	3	4	5
1	The current satellite store is convienent for operational effieciency					
2	Having such types of satellite store is important for the case company					
3	Such types of satellite store is fatique for both technician and satellite store keeper					

Section 05: Assesment of shortage of auxilary tools, Jigs and fixturesl in the case company		Score				
		1	2	3	4	5
1	The case company has enough auxilary tools, jigs and fixtures					
2	Auxilary tools, jigs and fixtures has no impact on operational effieciency					
3	Auxilary tools, jigs and fixtures has no impact on quality of the product					

Section 06: Assesment of workers skill in the case company		Score				
		1	2	3	4	5
1	The case company has enough skilled man power					
2	The production nature of the case company do not need skiled man power					
3	The current technicians skill affects the quality of product					

Section 07: Assesment of machine adjustment the case company		Score				
		1	2	3	4	5
1	The current way of production system of the case company needs frequent adjustment of machine					
2	Machine calibration has no effect on quality of product					
3	Machine calibration has no effect on operational effieciency					

Please, prioritize based on your opinion among the seven root causes, which one highly affects the operational performance of the case company using tick mark (√)		Score				
		1	2	3	4	5
1	poor plant layout					
2	un-necessary satellite store for processed material					
3	Workers skill problem					
4	Variaty of activities in a single ststion					
5	Shortage of auxilary tools, jigs and fixtures					
6	Un-balanced work process					
7	Machine adjustment problem					

IV Response rate and demographic analysis

A total of 40 questionnaires distributed and 40 is collected. The rate of response is 100%. The respondents' demography includes gender, age, education level, position, the root cause of waste of Operational performance of cargo bodies and trailers. So, they exhibited the following report in table below.

Age

		Frequency	Valid Percent	Cumulative Percent
Valid	Below 25 years	2	5.0	5.0
	From 25-30 years	22	55.0	60.0
	From 31-40 years	10	25.0	85.0
	From 41-50 years	3	7.5	92.5
	Above 51 years	3	7.5	100.0
	Total	40	100.0	

Gender

		Frequency	Valid Percent	Cumulative Percent
Valid	Male	38	95.0	95.0
	Female	2	5.0	100.0
	Total	40	100.0	

Work Experience

		Frequency	Valid Percent	Cumulative Percent
Valid	Below 1 year	2	5.0	5.0
	From 1-2 year	5	12.5	17.5
	From 2-5 year	10	25.0	42.5
	From 5-10 year	17	42.5	85.0
	More than 10 year	6	15.0	100.0
	Total	40	100.0	

Educational Back Ground

		Frequency	Valid Percent	Cumulative Percent
Valid	Diploma and certificate	25	62.5	62.5
	BSC/BA	13	32.5	95.0
	MSC/MA	2	5.0	100.0
	Total	40	100.0	

Employment Level

		Frequency	Valid Percent	Cumulative Percent
Valid	Low level	25	62.5	62.5
	Middle Management	10	25.0	87.5
	Top Managemnt	5	12.5	100.0
	Total	40	100.0	