Productivity Enhancement Through Introducing Lean Principles in Multi-Model Assembly Line

Muthuvel R, Mustakheem Sharieff, Thenarasu M

***Abstract:** Many organizations are now interested in a lean manufacturing principle and its implementation to show their presence in the competitive globalization market. Lean consist of several tools and techniques to eliminate the waste present in current system. Lean practicing organizations need to select right tool and technique for their own application. The basic idea of lean manufacturing is to provide a product of quality while ensuring that the product does not cost the customer too much. Lean philosophy based on customer centric with high product variety in existing manufacturing systems. Assembly lines have become more complex in terms of components and their storage space requirements. This results in handling the larger inventories against limited storage space and subsequent increase in cost. In this work a detailed study has been made at heavy equipment manufacturing industry to enhance their productivity in assembly line. The current state mapping (VSM) at heavy equipment manufacturing industry reveals that the Non-Value Added (NVA) are spread over the entire process such as extra processing, searching of material, inventories, etc., The main objective of this project is to resolve or reduce waste present in system through lean principle and to improve the productivity in assembly line. The benefits of introducing lean principle in assembly line include lead time reduction, manpower reduction, reduction in material handling, reduced space utilization, reduction of shortages and overall Productivity has increased to 30%.*

***Index Terms:** Value Stream Mapping (VSM), Kitting, lean principle, Assembly line, Productivity.*

I. INTRODUCTION

The concept of lean manufacturing was introduced by Japan, Lean manufacturing help in enhancing production processes and delighting up the employees work satisfaction level [1]. Lean Manufacturing will be act or used as an operational strategy to be achieving the organization aim by shortest lead time. Basically, it is guiding the managements with five principles to get success the organization. Principles are define value, define value stream, flow, pull, striving for excellence [2]. Organization to organization objective is different for adapting lean principle and it is practices, but most common goal or objective is to increase the productivity and reduce the lead time then improve the quality [3]. Lean Manufacturing having many tools and five principles. Tools are need to be handled appropriate since all are situation specific. We have to choose the right tool for right situation to get a better result.

There is no specific standard to using tools which needs to identify based problem scenario present in the company [4]. In lean manufacturing one of the concepts is customers and suppliers are should be treated as partners for the organization and need to motivate them extend our support to solve their problems. This will help the organization to compete with the global market [5]. TAKT time is a pulse of an organization, when it is live that organization also will be alive. TAKT time is maximum time per unit allowed to produce a product in order to meet customer demand. TAKT time will help in work scheduling a line and will bring the HEIJUNKA load leveling for the particular line [6]. Value Stream Mapping is one of the lean tools to identify the waste present in the system. Identifying the waste from complex situation is challenging job. With little modification from existing VSM procedure it can be used for complex situation also. There is no separate tool or system for complex situation. Same tool can be adapted for both simple and complex situation in a company. The same was analyzed and proved [7],[8]. In this project also deals with complex situation since it is multi model assembly line. VSM can be applied as Lead time reduction tool also, because Aircraft industry approached the VSM with an objective of Lead time reduction in Maintenance activity area. They applied the VSM in service process and identified the extra processing through VSM and eliminated that. They got significant result too [9],[10]. 5s and Kaizen are like both eye for an organization. It will yield continuous result and success to the organization. [11]. Survey from various articles that 60% of waste associate with inventory and also inventory is the major contributor to hide the problem as such. It will affect the profit and create loss to the company through storage and preservation cost [12],[13]. Bottleneck Process- which process cycle time is deciding the entire line output is called bottleneck process. This bottleneck process cycle time must be less than that of TAKT time to achieve the customer satisfaction. we can't eliminate the bottleneck process from the system but can minimize with KAIZEN [14]. In manufacturing industries, assembly lines must supply parts at workstations regularly to ensure the continuous flow of production. However, an internal material handling system is required to replenish stock on the line periodically in accordance with production plans. This usually means that parts are moved from an in-house warehouse to a workstation warehouse [15]. Parts Kitting is a frequently used method for delivering parts to assembly lines in a kitting policy [16]. All parts necessary for the assembly of one unit of the final product are grouped into one or more packages. Materials feeding has impact on both materials supply operations and receiving assembly operations.

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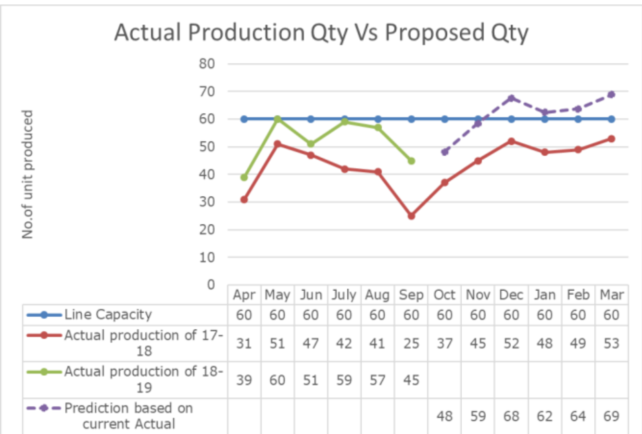
Kitting is used as a feeding method for materials, including continuous supply, sequencing and batching. [17],[18]. Toyota started a new production facility in San Antonio, Tundra has implemented a kitting process called the set pallet system [19]. Workstation or assembly mainly concerns which principle should be used for feeding materials. Reference [20],[21],[22] describes and derived three types of assembly station feeding methods, namely continuously, batch supply and kitting. U-Line concept is used to increase the effectiveness and efficiency of a line. It will give great amount of flexibility to line by the way of altering manpower based on daily TAKT time [23]. To gain the morale of works Line balancing is one of the most widely used concept. All worker needs to be treated as a same and almost same amount of work need to be extracted from each one of them. Morale is a step for success. [24], [25]. MCDM model-based priority rule was observed to be very huge in limiting the performance measures, such as lead-time, WIP, machine usage and machine queue related measures. The lead time for handling every one of the parts was accomplished as 23.5 days in press shop from 27 days [26]. As single piece stream help to keep up shop floor increments the activity hold up time at shot blasting and heat treatment station. This in the long run motivates shop floor administrator to go with flow metrics in structuring the layout and machine capacity with regards to optimized use [27]. Reference [28] states that the automatization of the profitability by 6% and diminished the workforce by 8.33% and thus expanding the benefit to the organization. The layout design was said to modify, with the end goal that every procedure happens under a solitary assembling unit and avoiding the transportation time and the labor required.

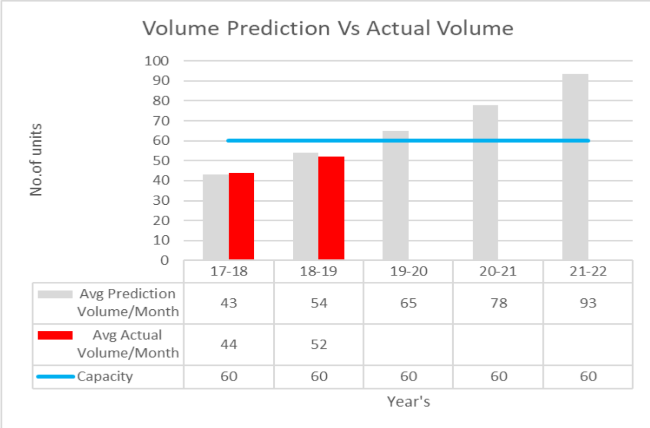
II. PROBLEM SCENARIO

Current capacity of assembly line is 60 Nos/Month. Right now, this line is getting order inflow equal to 60 units or more in the recent month. Graph [1] indicate 18-19 Capacity vs Actual production quantity. Populated the order inflow with respect to current year actual of 6 months. It is more than that of line capacity. To cater the customer demand, frequently employed operator in Overtime to complete the month production. Capacity addition is not possible in this stage since order inflow is equal or slightly higher than that. Only option left over is to Enhance the current capacity with improvements. Because capacity addition will lead to investment cost too.



Graph: 1 Actual Production Qty Vs Proposed Qty

In addition to that, this line order inflow will get increase by 20% every year based on the market prediction. As per our history of record real volume will be more than that of prediction. Some Productivity enhancement need to be done in this line to accommodate the current surge and upcoming year prediction volume. Graph [2] is explaining about upcoming years volume prediction volume quantity about the line. It clearly shows that every year customer demand is going to increasing



Graph [2]: Volume prediction Vs Avg Actual Volume

III. OBJECTIVE

By studying the situation present in the company, a problem scenario is devised and based on the requirements demanded by that situation objective of the project work is finalized. The objectives are formulated as:

1. To increase the line productivity by 30%
2. Improve the shop standards.

IV. LEAN REQUIREMENTS

Lean talk about five principles to increase the productivity in any of the production line. Table [1] clearly explain about lean principle and it is requirements. In this project we are going to implement the lean principles to achieve the productivity step by step. We strongly believes that lean principles will help us to improve the productivity based on literature survey. From this lean principle arrived it is requirements for implement those five principles.

Table [1] Lean system and its requirements.

Step	Lean Principle	Requirements
A	Define Customer Value	Takt Time implementation
B	Define the value stream	Identify and Eliminate NVA's
C	Flow	Create the flow in line (single piece flow)
D	Pull from customer back	Work for customer demand
E	Striving for excellence	Minimize the losses and Maximize the production

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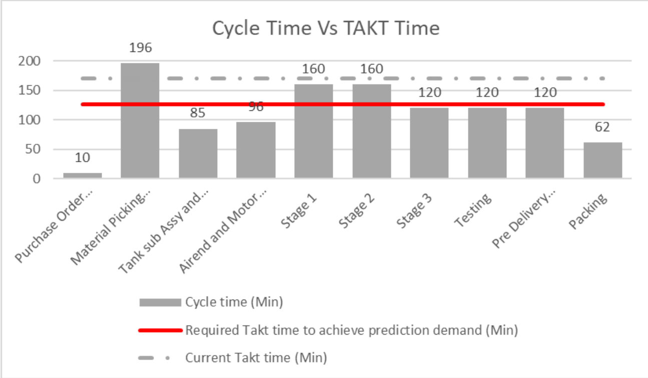
A. *TAKT Time implementation*

Started to plot a graph with respect to TAKT time and process wise current cycle time for current scenario. Current TAKT time of the line is 170 Min. Graph [3] Cycle time Vs TAKT Time explain the current situation. Based on the predicted volume TAKT is calculated as a 127 Min for this line. We have to complete each operation within 127 Min to achieve the prediction demand in upcoming year. Three process cycle times are above the calculated TAKT time. This graph [3] give clear view about our work should be where. Material picking and issuing and then stage1 and stage2 Cycle Time are above the required TAKT time value. Some other area having very less cycle time compare to required TAKT time. Both scenarios are need to be addressed by cycle time reduction or line balancing. Because low cycle time operation will demoralize the operator who worked in higher cycle time operation. First we need to focus the operation which is having higher cycle time than the TAKT time. Through which can ensure customer satisfaction first. As a lean practitioner first focus should be customer satisfaction.



Graph [3] Cycle time Vs TAKT Time

B. *Value Stream Mapping*

Value Stream Mapping is a graphical representation tool to visualize and identify the waste present in the entire organization. To identify the Non-Value added (NVA's) in organization. we have drawn the current state Value Stream Mapping (VSM) for that particular line

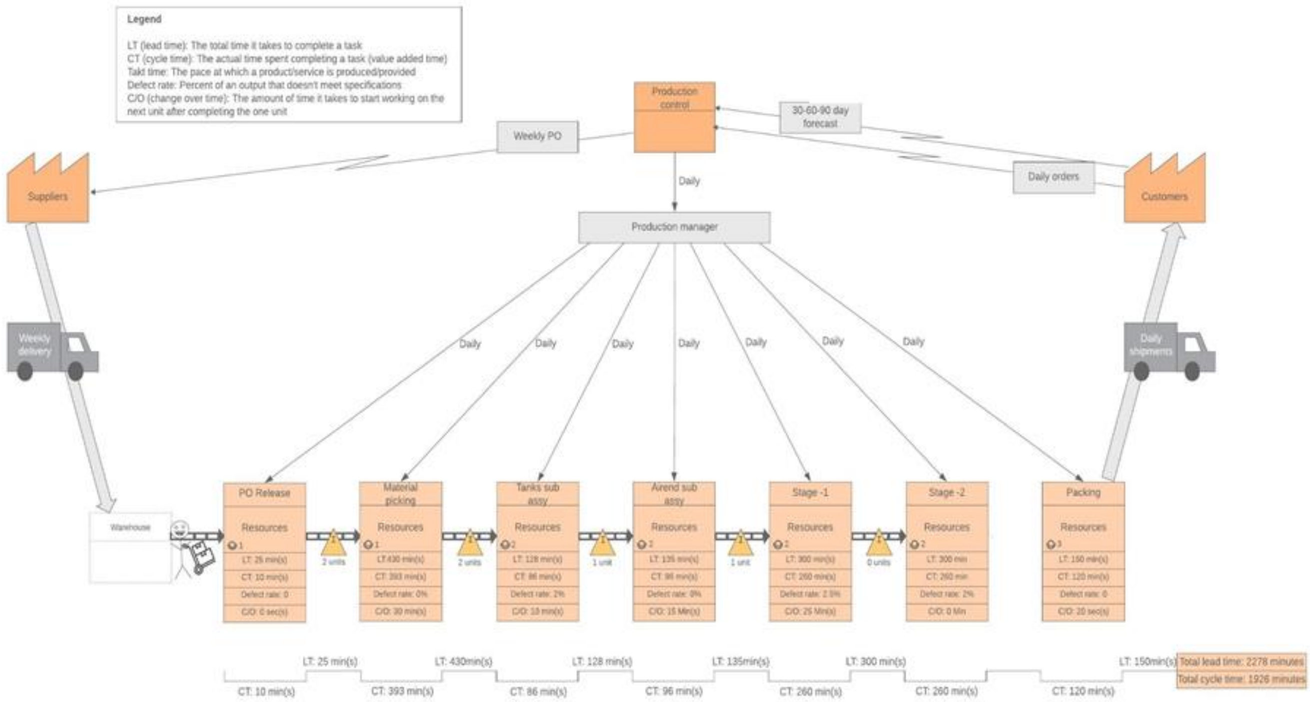


Figure [1] Current state VSM

Current VSM shown in the figure [1] was made in a conventional method for one of the runner models (Premium model) to understand the waste present the current system. VSM start with customer and end with customer. VSM gives information flow Vs material flow or entire system from Customer to Customer. Since in this project is focusing on productivity enhancement of assembly line non-value added points identified related to PO release to Packing alone. It gives clear view about entire process flow and Value-added time and Non-Value-added time details. When we studied the process from PO release to packing, we found 60% of activities are Non-value added one. Only 40% of activities are identified as a value added. Graph [4] explain the value added and Non-value added present in current system. Overall observed 191 points and with respect to different waste category in entire process with current VSM. Macro level classification has been done like project and kaizen points for identified points of VSM. 145 points are related to kaizen and 46 points related to projects. Table [2] give overall points classification with respect to 7 waste categories.

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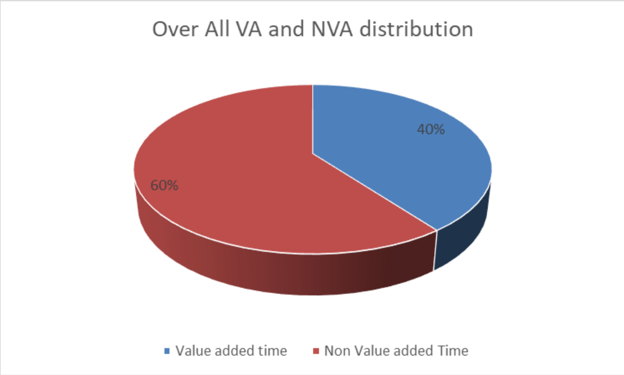

Graph [4] VA and NVA distribution.

C&D -Flow and Pull from customer.

This flow and pull will be implemented with management support. Single piece flow production has been implemented in this line before this project initiation. So just we need to sustain that to attain the entire lean step. Step-4 Pull from the customer demand. To create a pull system introduced new concept in planning area. Runner models are moved to bin system Build To Stock (BTS) and stranger model are moved to Build To Order (BTO). Because of this initiative line will run from the customer pull. Push system of production has been stopped in this line.

E -Striving for Excellence

This step talk about continuous improvement and it sustains. Continuous improvement will be achieved by eliminating waste present in the system. To eliminate NAV's four projects has been identified from the major NVA distribution list. Table [3] Major project list gives you details where we are going to work and what we are going to work.

Table [3] Major project list

S.NO	Major Project's	Current CT in min	Expected Final Time in min	Expected time reduction in min	% of time reduction in overal lead time
1	Material kitting project	196	136	60	6%
2	Tank sub assy cycle time reduction	85	68	17	2%
3	Airend and Motor coupling	96	80	16	2%
4	Pre Delivery Preparation cycle time reduction	120	90	30	3%
	Total	497	374	123	12%

Project 1: Material Kitting Project

Data Collection:

Assembly line is high variety model mix-up line. To understand the model mix-up and variety studied the last 18 Months Actual production data from Apr-17 to Sep -18 for this line. Then segregated the production into three types with based on thumb rules.

Runner : Every month 1 unit minimum present
Repeater : 3 months once 1 unit minimum present
Stranger : Others than above category

Table[4] shows that, totally 845 units assembly & 166 Variety were produced in this time span. Only 8 Variants are produced repeatedly and others are produced often. In an average every month Minimum 20 to 25 Model variety is being produced in this line.

Table [4] : Model variants

Type	No.of Variants	Quantity	%
Runner	8	347	41%
Repeater	23	226	27%
Stranger	135	272	32%
Total	166	845	100%

Kitting Project

From VSM input Major projects identified and shown in table[3]. Kitting project has been initiated for de-bottleneck the Raw material picking and issuing process. To understand the Raw material picking and issuing process we have studied the process flow of raw material picking and issue. Figure [2] gives the details about raw material picking process.

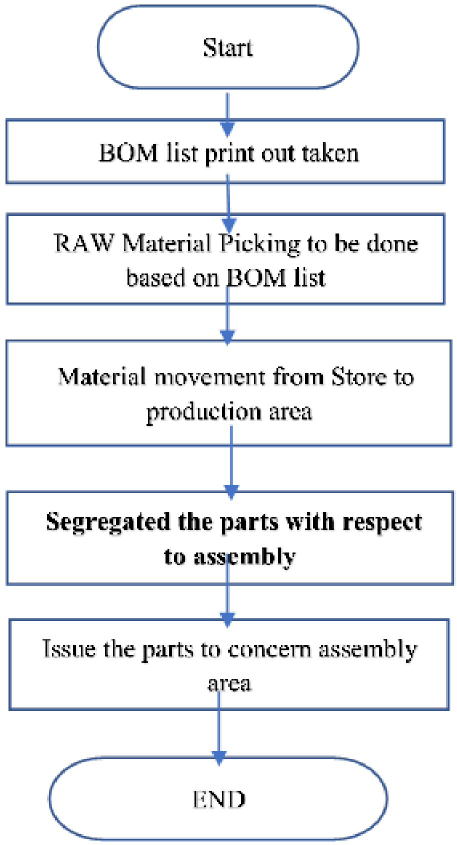

Figure [2]- process flow of raw material picking and issue

Area of improvement:

From VSM input, Process 4 was identified as Extra processing work waste and can be eliminated by introducing kitting concept in this line. As per the current process flow initially they are picking material based on the part no and quantity for the particular unit and issued to line. The same got segregated as the assembly process which available. These two activities can be combined as a one activity by picking the materials as per assembly needs. Figure[3] indicating the same. Following action need to be done for combing Process 4 with Process 2.

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1) Develop a new module Production Bill of Material (PBOM) in our existing ERP system for kitting the material apart from regular BOM.
2) Assembly process wise segregation need to be done for all existing model in PBOM.
3) Material picking process will be based on New Developed module PBOM.

Assembly time reduction

As per the TAKT time study, Tank Sub assy and Motor and Airend sub assy taking less time. We need not to act now since it is well within limit. But Stage 1 and stage 2 are above the required TAKT time. To reduce the stage CT, we have planned to balance the activity of stages. Planned to move some activity from stage to sub assembly since its need to be reduced with respect to required TAKT time. Before moving stage activity to sub assembly as a part of balancing, we did study the sub assembly activity with respect to ECRS (**E**liminate, **C**ombined, **R**e-arrange, **S**implify) method to reduce the cycle time furthermore from existing one. As a part of LEAN journey, we need to get the Consensus of each persons before implementing. To earn the sub assembly support to balancing activity reduced the cycle time in their exiting one.

Tank Sub Assembly Process:

Table [5] Tank sub assembly process explain the activity macro level and its time. Action has been identified in simplify method and implemented in three area. Reduced the Tank sub assembly time from 60 min to 41 min.

Table [5] Tank sub assembly process

S.No	Process	Before time	E	C	R	S	Before Process	After Process	After time
1	Top plate removal	10				■	Top removal with the help of sling with two side hook setup 	Dedicated holding device manufactured for holding the top plate. There is no sling. Only one hook is enough to lift the top plate 	7
2	Separator inserting	13				■	Separator lifting by manual and inserting into tank 	Special holding device manufacturing and used for separator inserting 	8
3	Top plate fixing and torque	6				■	1) Pre tightening will be done by impact wrench 2) Final tightening will be done by manual torque wrench to ensure proper torque on bolts 	1)Pre tightening and final tightening combained by pre setted Oil Pulse tool. 2) To improve the ergonomic oil pulse tool loacted in top with spring balancer 	2.5
4	MPV fixing	5					Open the carton box and putting 'O' -Ring on bottom of MPV and fixing with top plate	Open the carton box and putting 'O' -Ring on bottom of MPV and fixing with top plate	5
5	Safety valve and other small part fixing	26			■			Layout improvement to access part and jib crane introduced to eliminate waiting time	18.5
	Before Time	60						After	41

Motor and Aired Sub Assembly:

Like Tank sub assembly, In Motor and Airend sub assembly also approached through ECRS method and identified action to reduce the cycle time. Table [6] Motor and Airend sub assembly process explain the macro level process and its time. Before and after implementation status and result also covered in this table [6].

Table [6] Motor and Airend sub assembly

S.No	Process	Before time	E	C	R	S	Before	After	After time
1	Loading the motor in stand	3			■		Motor will be loaded on the stand with the help of EOT crane 	Motor will be loaded on the trolley 	3
2	unloading & Loading the Airend in stand	7			■		Airend will be loaded on the stand with the help of EOT 	Airend will be loaded on the trolley with the help of EOT 	7
3	Coupling dismantling	3				■	Coupling dismantling with the help of spanner 	Coupling will be dismantling with the help of battery operated gun 	2
4	Fixing coupling in Airend	8				■	1) Coupling will be lifted manually and initial alignment will be done 2) by the help of manual hydraulic pusher coupling will be fixed in shaft  	1) coupling handling trolley fabricated and given to line to avoid manual lifting 2) Automatic hydraulic pusher given for pushing the coupling instead of manual pusher  	4
5	Fixing adapter ring in motor	12			■		Adapter ring will be fixed in motor with the help of EOT crane.	Adapter ring will be fixed in Airend with the help of EOT crane	12
6	Fixing coupling in motor	15				■	1) Coupling will be lifted manually and initial alignment will be done 2) by the help of manual hydraulic pusher coupling will be fixed in shaft 	1) coupling handling trolley fabricated and given to line to avoid manual lifting 2) Automatic hydraulic pusher given for pushing the coupling instead of manual pusher 	8
7	Mount the Airend in adapter ring	13				■	With the help of EOT crane Airend will be lifted and aligned towards motor shaft and then mount it 	with the help of Scissor lift Airend and motor shaft alignment will be done 	6
8	Fix the rubber element and fix the guard of coupling	4					Manually rotate the shaft and insert the rubber element in this and assembly the guard 	Manually rotate the shaft and insert the rubber element in this and assembly the guard 	4
	Total	65							46

Pre-Delivery Preparation time reduction (PDP).

To reduce the PDP time, studied the process with process flow chart and found major waste are associated with cleaning and walking. Figure[4] Pre Delivery Preparation Process flow chart is clearly explain this.

S.No	Activity	Symbols: ○	⇨	□	D	▽	Distance moved (Mtr)	Time (min)	Remarks
1	Move the door trolley near to unit						2	2	Man Movement
2	Remove the doors doors of motor side and Airend side and placed in trolley							8	
3	Move the door trolley to loaction with doors						2	2	Man Movement
4	Apply Rust preventive oil on Intake valve							10	
5	Move to thermal valve block						1	1	Man Movement
6	Apply Rust preventive oil on thermal valve block							5	
7	Move to MPV						0.5	1	Man Movement
8	Apply Rust preventive oil on MPV							4	
9	Move to adapter						2	2	Man Movement
10	Apply rust preventive oil on coupling.							6	
11	Move to tool trolley and take spanner and bolt and return to adapter ring area						2	2	Man Movement
12	Ttighten the coupling guard							5	
13	Move to tool trolley and replace the tools with orginal position						2	2	Man Movement
14	Take the cloth and start cleaning the internal parts (Right side)							2	
15	Cleaning the shroud inner side							12	
16	Cleaning the motor							9	
17	Cleaning the Airend							7	
18	Cleaning the Tank							6	
19	Cleaning Motor and Airend mounting bracket							4	
20	Cleaning the base							8	
21	Then move to front area						1	1	Man Movement
22	Cleaning the DCV hose and fiter box							3	
23	Then move to left side						2	2	Man Movement
24	Cleaning the inner parts							10	
25	Then move to back side						2	1	Man Movement
26	Cleaning the Noise control box							4	
27	Cleaning the control panel back side							8	
28	Then move to control panel						1	1	Man Movement
29	Tie the Eye bolt with cable tie and pack the spares and kept it inside the control panel							9	
30	Then cleaning all four outer side							26	
31	Then pick the ladder and place it near to machine							3	
32	Claim up and cleaning the top roof sheet							7	
33	Fill the check sheet of PDP							4	
34	Offer the unit to LQA check							20	
35	Do the correction activity based on LQA inputs							16	
36	Tie the silica gel in 5 places							12	
37	Close all doors and move the machine to Packing						20	15	Man Movement
							Total Time	240	

Figure [4] Pre-Delivery Preparation process flow chart

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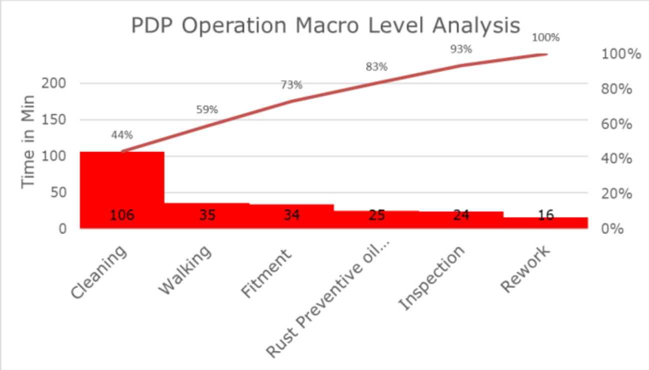
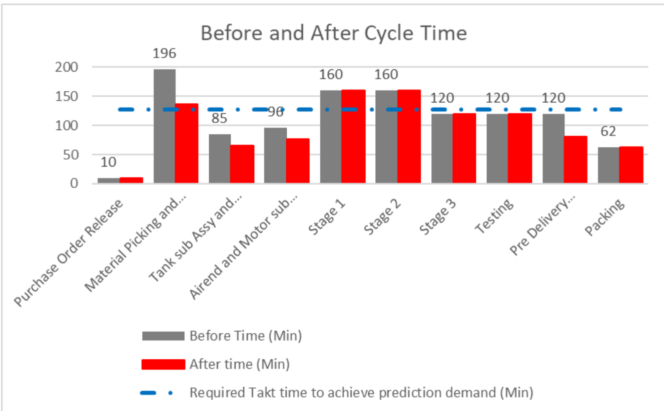


Graph [5] Pre-Delivery Preparation Macro Level Analysis

Graph [5], indicating 'cleaning' is carried out predominately compared to other activity. Then man movement is more rather than operation. Man movement is one of the lean waste and Extra processing also present in Pre delivery preparation area in the form of Rust preventive oil application for aluminum parts. To reduce the cleaning activity action have been identified and implemented.

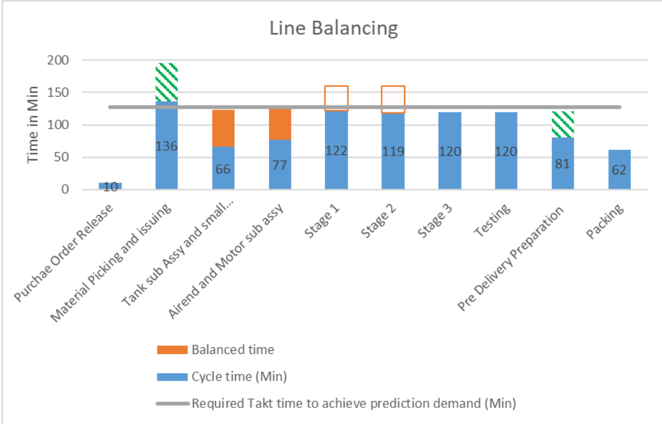
Category	Before Time (Min)	Activity	After Time (Min)	Improvement implemented
Cleaning	106	Normal cloth used for cleaning the compressor Interecate places cleaning is fatique job to clean and taking more time	80	Lint free cloth can be used for cleaning instead of normal cloth Vacuum cleaner will be introduced for cleaning
Walking	35	No.of process is more	20	No.of process will be eliminated by simplifycation or eliminate the process
Fitment	34	No action	34	No action
Rust Preventive oil application	25	Rust preventive oil apply over the aluminum parts in PDP area	0	By adding anodizing procss to supplier end for Aluminium parts, Rust prevent oil coating can be eliminated
Inspection	24	inspection combained of data verificatin and austhetic (Visual) checking of units as per standards	18	Data verification can be moved to prior stage (Leak test), so that inspection time will be reduced
Rework	16	Painting touch up work is more at PDP due to material handling	10	Metal to metal contact will be avoided in assembly area by improving material handling system to reduce the rework at PDP
	240		162	

After implementing above action we got result like Graph[6]. Some of the area below the required TAKT Time still some of the operations cycle above the TAKT time. So, we need to do line balancing and made it at bar with our new TAKT time requirements.



Graph [6] -Before and after comparison of Cycle Time

Further to this improvements Stage1 and Stage2 CT balanced with Sub assembly to bring the cycle time with TAKT time. Possible stage Activity moved to offline and attached with existing sub assembly area. Graph [7] shows the final result of this project. Current bottle neck operation is Material picking and issuing with 136 Min cycle time. This line output lies with operation only.



Graph [7] Line balancing

V CONCLUSION

This project work aims to provide detailed research on better practice of material handling by using kitting system and its impact on manufacturing. Various benefits were observed on the assembly line by implementation of the kitting system as compared to line stocking. The main factor for kitting is the high variation of the end product in line production. This variation requires a lot of space on the side of the line to store all parts, this space creates time for operators to walk and find. The following objectives have been set in consultation with the plant management: reduction of kit cycle time, inventory costs and area. The advantages of introducing the kitting concept in the assembly line include reduction of lead time, reduction of manpower, also reduction of material handling, occupancy, part shortages and overall productivity has improved to 7%. Kitting provides not only quantifiable results but also intangible results like decrease in searching time, increase in shop floor control, increase in end product quality, reduced waste and packaging, lesser rework, fatigue reduction of the operator. The assembly areas become more flexible and free from leftover components. Part availability and shop standard improvement has improved due to kitting concept. Also, product changeover can be easily accomplished. Kits being easier to learn, reduces the training cost of workers. By implementing lean tools overall productivity got increased from 2.6/day to 3.7/day in this line.

Future VSM has to draw based on current improvement and take it up to further Non-Value added time elimination. This is not a one time activity to stop the process. It is cyclic process to identify and elimination of waste.

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