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Optimize Efficiency of Assembly Line by Time Study and Line Balancing

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ABSTRACT

Assembly line balancing is to know how tasks are to be assigned to workstations, so that the predetermined goal is achieved. This requires logistics systems that can support production in small lot sizes. Since continuous material feeding systems resulted in increased operator walk and search time an attempt to increase production throughput is made. In this paper best line feeding systems are implemented to support assembly line production systems to reduce the downtime at assembly line due to material shortage. The data is collected for downtime due to material shortage from each assembly line and analysed for effects on production time. Time study is carried out to determine value added and non-value added activities and reduced them. Hence continuous supply system has been replaced by lean supply kitting system which resulted in reduced assembly line downtime and reduction in material flow throughout the system.

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I. INTRODUCTION

The main purpose of the project is to reduce and increase the amount of Apart from past or recent times, the aim of production businesses was always to produce goods with low costs and high profit. Economic crisis showed that it is necessary to focus on reducing costs. Corporate management has to focus on revealing and solving problems. The portfolio of solutions of these problems is globally large. It consists of some systems of e.g. lean manufacturing, six sigma, and theory of Constraints or elder approaches through simple methods. Hiding problems of production lines by high stocks is totally a wrong solution in mass production. The concept of lean manufacturing was introduced in Japan, and the Toyota production system was the first to use lean practices. Lean manufacturing helps in enhancing production processes and boosting up the employees job satisfaction. Lean manufacturing is different from traditional manufacturing. The traditional concept focuses on the inventory of the system, whereas lean manufacturing opposes this concept. The 'Lean' concept considers inventory as a waste in the organization. Understanding the differences between traditional and lean manufacturing is very necessary for all industries in order to continue with lean principles. Introducing lean manufacturing in any type of industry has a straightforward impact on manufacturing processes. Today people have a different perspective on manufacturing processes. They understand that the value of a product is defined from the customer's point of view, not from an internal manufacturing point of view. They understand that the value of a product is defined from the customer's point of view, not from an internal manufacturing point of view. Lean manufacturing also looks ahead on the elimination of wastes from assembly lines and inventory. Line Balancing is a classic Operations Research optimization technique which has significant industrial importance in lean system. The concept of mass production essentially involves the Line Balancing in assembly of identical or interchangeable parts or components into the final product in various stages at different workstations.

Although we will formally define a kit in the next Section, for discussion purposes a kit may be generally

viewed as a container which holds a specific assortment of parts that are used in one or more assembly operations in the plant. In contrast to continuous supply, where each part number is generally presented in a separate container, kitting means that parts are delivered and presented to the assembly operations in pre-sorted kits, with each kit containing parts for one assembly object. In many cases, each kit is delivered and presented in some form of carrier, such as a box or a trolley.

II. LITERATURE REVIEW

Lean and agile manufacturing is a very vast field and Line Balancing in industries is also very important. Many times in conferences this is main topic of discussion and many students and scholars also publish their work on this topic. Aim is resource conservation, climate protection and cost savings, while the users have permanent access to the energy they need. It is connected closely to environmental management, production management, logistics and other established business functions.

Ergonomic Issues in Lean Manufacturing were presented by Bianca and Anca (2016) [1]. They pointed out the ergonomical issues that occur after the lean acceptance. They also stated that more and more companies are interested in the well-being and satisfaction of human resources. Their paper presents a qualitative briefing and review in order to understand the evolution of lean implication.

They studied the differences between lean theory and lean practice, the employees needs for feedback and direct involvement in the company, stress reduction in lean manufacturing through reporting all misunderstandings, the inside collaboration between employees and managers. Their work illustrates a comprehensive literature review of the last decade regarding the possible impact, both positive and negative of lean manufacturing on the occupational ergonomics.

Bortolini et al. (2016) [2] published their work on Material Exposure and Part Attributes in the Manual Assembly Line Balancing Problem. Their research proposes an innovative optimization model distinguished by different objective functions to properly balance assembly lines considering the aforementioned features. The model is tested and validated with a real industrial case study. The results demonstrates the importance of including material exposure and the optimal material storage within the assembly station in the assembly line. They concluded that proposed assembly balancing model suggest remarkable results if the minimisation of the assembly line takt time (*min TT)* is considered. Their future research includes ergonomic aspects in the proposed objective functions.

Emanuel Falkenauer (2015) [3] discussed that Line Balancing (LB) is a classic, well researched Operations Research (OR) optimization problem of significant industrial importance. His work identified a number of aspects of the line balancing problem that are vital in industries such as automotive, yet that have been either neglected in the OR work on the problem, or handled separately from each other. According to his work experience, a line balancing tool applicable in those industries must be able to handle all of them simultaneously that gives rise to an extremely complex optimization problem. The complexity of the problem, and the need to solve it quickly, may explain why there appears to be just one commercially available software for solving it, namely OptiLine by optimal design.

Application of Lean Manufacturing Tools in the Food and Beverage Industries was presented by Lopes et al. (2015) [4]. This work presents the application of some LM tools, and the corresponding shift in philosophy, in two Portuguese companies of the food and beverage industries. Main implementation issues are presented and discussed; followed by the results obtained from the application of LM tools in the production system of these companies. Significant gains were obtained in both companies and, more importantly, it instils a continuous improvement culture and increases production flexibility while reducing lead times. They concluded that as a future work, a follow up on the level of lean implementation and cultural change in the companies is advised. Also, future work may focus on more accurately quantifying the impact of machine design changes and the impact in inventory reduction.

Marek Piatkowski (2015) [5] studied the basics concept of lean manufacturing. The work also stated the two types of efficiencies- true and apparent. His studies concluded that improvements in efficiency that ignore the production schedule will result in the waste of overproduction and push overall company efficiency in the wrong direction. Improvements in efficiency display their value by lowering costs. When evaluating efficiency, the key factor is the necessary production quantity: you must consider how the necessary items can be manufactured with the fewest man-hours possible in the best time.

III. OBJECTIVES

1. To reduce or eliminate nonproductive and non-value added time.
2. Increase efficiency of assembly line.
3. To fix standard time for doing the activity.
4. To develop standard data for future reference.
5. To improve process and product quality.
6. Remove sub assembling out from line.
7. Reduce manpower requirement per machine.
8. Improve material handling activity and time required.
9. Equal distribution of work contain in all stages.
10. One piece material flow. Smart kitting and sequence material logistic concept.
11. Tools distance and walking distance reduction.
12. Correct and advance tooling selection for assembly operation.
13. Reduce workspace if possible.

IV. SCOPE

New cost reduction techniques are developed which focus precedence, conjoining tasks and increasing operation times as well as to its computational efficiency.
A new improvement in priority rule is discussed which shows that production cost is the result of both production time and cost rates. The lowest standard deviation of operation efficiency, the highest production line efficiency and the least total operation efficiency waste are studied to find out the optimal solution of operator allocation.
Experiment on a new heuristic assembly line balancing in real-life air compressor assembly plant case results in shorter physical line length and production space utilization improvement, because the same number of workers can be allocated to fewer workstations.
To reduce and improve the waste management system

V. METHODOLOGY

Line balancing is commonly technique used to solve problems occurred in assembly line. Line balancing is a technique to minimize imbalance between workers and workloads in order to achieve required production rate. This can be done by equalizing the amount of work in each .Here the job is divided into small portion called “job element”. The aim is to maintain production at an equal rate.

Followings are the key elements used in organizations:

- **SMED/setup time Reduction-**Lean Manufacturing targets reduction of setup time and changeover time because it consumes critical working time and reduces proper utilization of machine and operator time. This can be achieved by sequenced and structured work instructions to perform the job.
- **Kanban -**Kanban is a shop floor tool which communicates customer requirement from downstream to upstream worker. Once product is withdrawn from finished goods against customer demands to replenish the moved quantity it is replaced with coloured card (or electronically).
- **Total Productive Maintenance -**Total Productive Maintenance (TPM) promotes basic preventative maintenance job to operator itself so that break down time of machines is reduced.
- **Batch Size Reduction -**Lean Manufacturing calls for smaller batch size production. The word single piece flow means it tends to one part at a time to be produced when operating for various types of product.
- **Poka Yoke -**Poka Yoke means mistake proofing. This involves bringing a system which eliminate human mistakes in term of quality, safety and other process parameters to ensure quality and safety in the manufacturing lines.
- **The Five S’s -**The 5S is a lean tool which consists of five steps Seiri, Seiton, Seiso, Seiketsu, Shitsuke and taken from Japanese language which aims to improve work place efficiency.

i) Seiri: It refers to the action of sorting out wanted and unwanted material in and around workplace.
ii) Seiton: Seiton or set in order means every object (material, tool or instrument) must have a designated place to keep and every place have is the same object.
iii) Seiso: Seiso, is the third step in "5S", speaks about clean and shine. Everybody is caretaker of its workstation and should see to clean all the commodities in and around workplace and make it shine.
iv) Seiketsu: The forth S of "5S", is seiketsu, it means standardization. It consists of defining the standards by which personnel must measure and maintain 'cleanliness'.
v) Shitsuke: The S of "5S" is Shitsuke, which means 'Self Discipline.' It stands for promise to maintain the first 4 S as a way of life.

- **Quality at the Source-**Quality at the Source means that quality should be built into the production process in such a way that defects are identified and eliminated at the source. The main responsibility for quality inspection is done in-line by workers, not by separate quality inspectors who inspect sample lots.
- **Kaizen** –Kaizen means small improvement. To maintain continuous improvement activities throughout the organization Kaizen culture should be created and maintained.

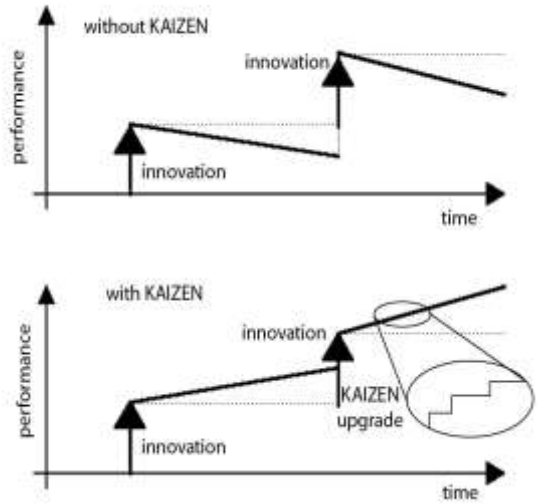
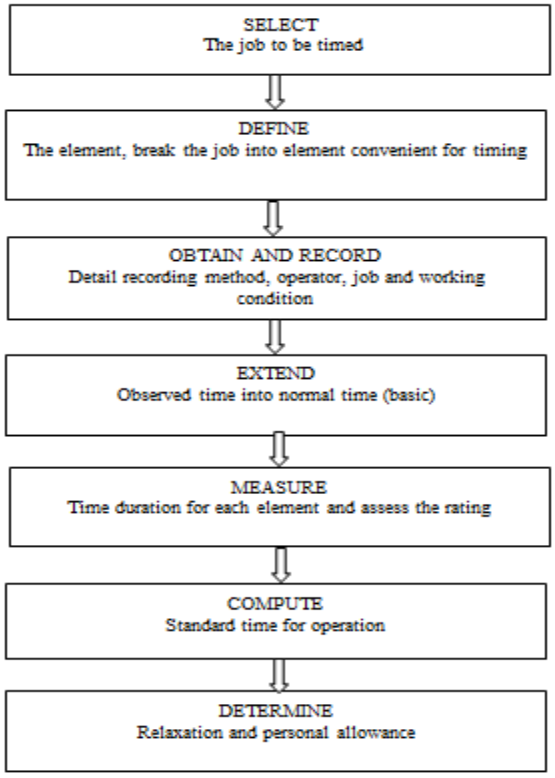


Fig.1:- KAIZEN

- **Production Levelling (Heijunka**) -Production levelling, also called production smoothing, aims to distribute production volumes and product mix evenly over time so as to minimize peaks and valleys in the workload. Any changes to volumes should be smoothed so that they occur gradually and therefore in the most non-disruptive way possible.

- **Standard Work -**Standardized work means defining work and process instructions are well defined with full details of operation or process and parameters.



VI. RESULTS AND DISCUSSION

1. Terms in Line Balancing Technique

In assembly line balancing system, there is various term normally used

i. Cycle Time

Cycle time is the Maximum amount of time allowed at each station. This can be found by dividing required units to production time available per day.

$$Cycle\,Time = \frac{Production\ time\ per\ day}{Units\ required\ per\ day}$$

ii. Lead Time

Summation of production times along the assembly line.

Lead Time=

∑ Production time along the assembly line

iii. Bottleneck

Delay in transmission that slow down the production rate. This can be overcome by balancing the line.

iv. Idle Time

Idle time is the time specified as period when system is not in use but is fully functional at desired parameters.

v. Productivity

Define as ratio of output over input. Productivity is depends on several factors such as workers skills, jobs method and machine used.

$$Productivity = \frac{Output}{Labour\ Input\ Production\ time\ Per\ day}$$

Product	No of work Stations	Takt time	No of operators	AT	ST (min)	Efficiency
GA 45 VSD FF	11	54	11	435	280	64.36
GA 45 VSD FF	11	54	11	435	300	68.96
CPVS	11	54	11	435	330	75.86

Where AT =Available Time

ST =Standard Time

Table No 1:-Time Study before Project Start

- **TIME STUDY**

As per standard time study procedure, a skill well train worker should be deployed to complete the work and activity will be video recorded. In addition that stop watch for record timings for macro level time recording. In a line-balancing, there is a finite set of work elements, each having a fixed processing time which specifies the permissible ordering of the elements. The complexity is to assign the elements to an ordered sequence of stations. The assembly line is a flow oriented production system where the productive units performing the operation referred to the workstation and the work pieces move from one station to another station with some transportation system. There will be a complex area in the production line or technically known as the bottleneck workstation.

First of all, to know the production capability of each individual station, detailed cycle time study at each workstation is carried out. Cycle time study is done for repetitive cycles.

CS	Element Description	BT	ST	FS	Total Time in Station	N.O	Timing According to No Of Operators
1	Mount Buffers On Frame	12	13	1	1:46:00	2	0:53:00
2a	Element motor	71	81				
2	Mount Element	11	12				
3a	Vessel Assembly	71	79	3	2:13:00	2	0:66:50
3	Vessel Mounting	50	54				
5	Control Panel	64	70	5	1:10:00	2	0:35:00
7	Cooler Assembly	117	130	7	2:10:00	2	0:65:00
9	Drains	90	100	9	1:40:00	2	0:50:00
11	Canopy Stage	69	76	11	1:16:00	1	1:16:00
					9:35:00	11	

Where CS= Current station BT= Basic time

FS= Future station ST= Standard time

NO = Number of operators

Table No 2:- Total Time Study for Line 1

- **LAYOUT**

Layout is the physical setting of a production system in production facility. Layout planning is the physical organization of elements of a production system by considering the physical constraints and resource requirements of and expected outcome from the system. Physical setting of a production line can affect the efficiency of a production system, i.e. supply chain performance in a facility can be improved by quick delivery of parts in a system with short distances between related locations, and it is very critical to consider specific requirements of the designed line and modify the layout plan accordingly.

There are 4 basic types of layouts:

1. Process Layout

2. Product Layout

3. Fixed-position layout

4. Service Layout

OLD/PRESENT LAYOUT

K	KITTING TROLLEY
V	VESSEL
2B	TWO BIN
ST	SEQUENCING TROLLEY
VF	VESSEL FIXTURE
EF	ELEMENT FIXTURE
MF	MOTOR FIXTURE

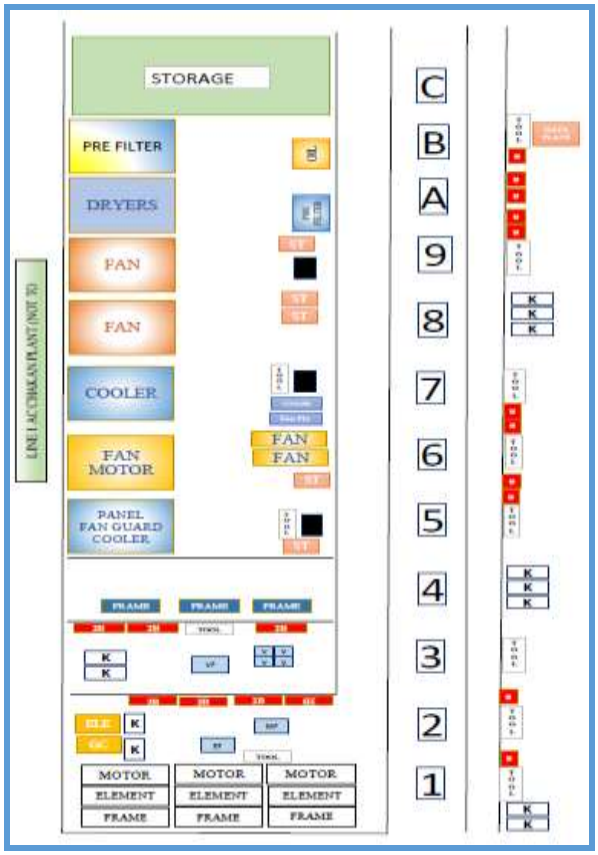
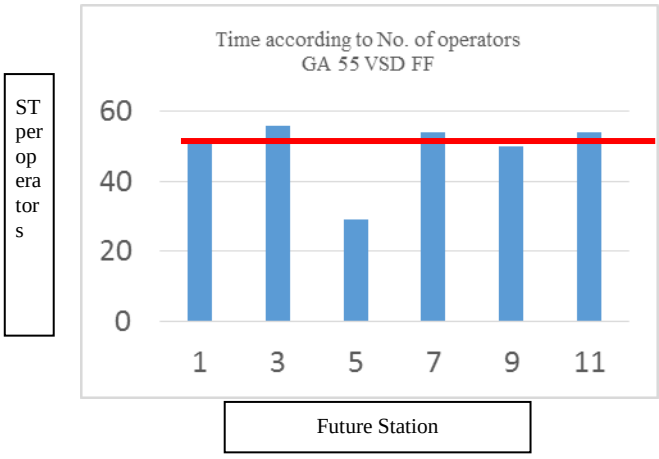


Fig 2: Present layout

VII. ANALYSIS

Station no	Element Description	Future Station	Total Time in Station	No of Operators	Timing According to No Of Operators	Available Time (Minute)	Customer Demand	Takt Time (Minute)
1	Mount Buffers On Frame							
2	Element motor assembly coupling	1		2	0:51:30	435	8	54
3	Mount Element Motor Assembly		1:43:00					
4	Vessel Assembly	3		2	0:56:00			
5	Vessel Mounting		1:52:00					
6	Control Panel Assembly Wiring	5	0:59:00	2	0:29:00			
7	Cooler Assembly,Dryer Assembly, Hose Connection	7	1:48:00	2	0:54:00			
8	Drains connection and wiring and WSD/EWD	9	1:40:00	2	0:50:00			
9	Canopy Stage	11	0:56:00	2	0:54:00			
			0:55:00					

Table No 3:- Workload Balance And Correct Number Of Resources To Make Line Efficient



VIII. NEW MODIFIED LAYOUT

Major changes to be done.

1. Rearrangement of kitting trolley movement.
2. Start the actual assembly from current station 2 distribute the workload accordingly.
3. SA-2 (Element Sub assembly) layout rearranged.
4. SA-3 (Vessel subassembly) layout rearranged.
5. Kitting trolley clubbed into one.(i.e. 1 kitting trolley for 1 compressor)

Layout for SA-1 and SA-2 is changed.

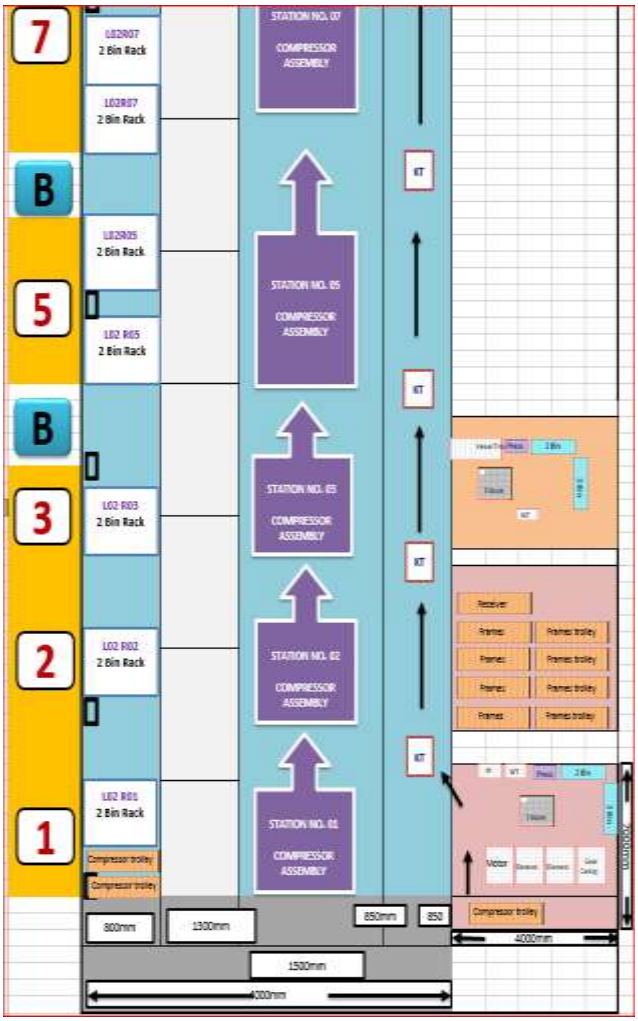


Fig 3: New layout

Benefits.

1. Single piece flow.
2. Easy handling of kitting trolleys.
3. Better space utilization

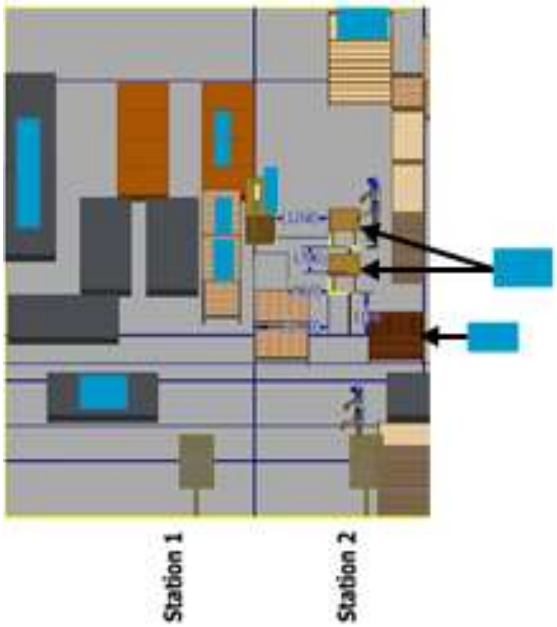


Fig 4: Layout for SA2

- **Benefits of the proposed layout for SA 2**

1. Better space utilization.
2. Arrangement for two motor fixtures for AC and CP (Saving
   Approx. 5 min in it)
3. One piece flow of the material with one kitting trolley per compressor

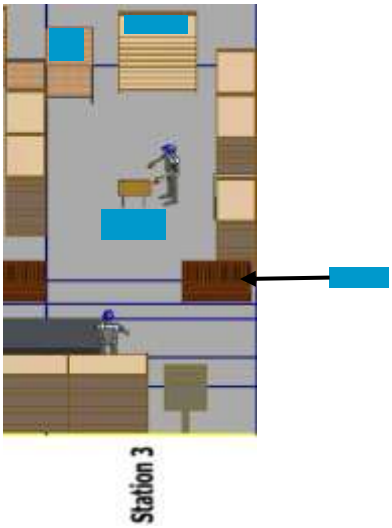


Fig 5: Layout for SA 3

- **Benefits of the proposed layout for SA 3**
  1. Reduction in the unwanted movement
  2. Better arrangement for the kitting trolley movement

IX. IMPROVEMENTS ON LINE 1

sr.no	ISSUE	ACTIONS
1	Currently they are using long spanner and the bolt to fix the flange of CPVS MPV	Need to ask supplier for the same so as to get new tool 
2	Stools on the line are too short due to which operator has to move it much frequently while mounting cooler or above panels causing additional time to activity	Provide one longer stool so that within single arrangement they can easily 
3	Using spacers below the CPVS motor to balance it	Provide proper arrangement to balance it 
4	For CPVS gear casing it is not possible to use nut runners while assembly	Need to check about the space available for the bolt tightening and discuss the same with engineering 
5	Vessel on the fixture is hand tightened using bolts causing more time for assembly	We can provide the arrangement with studs and the wing nuts 
6	The hose of nut runner is very longer ,causes obstruction to work	Need to tie the hose and also the issue will be resolved with new layout 

7	Long spanner is used on the line for tightening elbow	Provide socket that can be attached to runner 

X. CONCLUSION

1. As we have seen after line balancing and improvements we get efficiency gain 33%.
2. The fatigue and motion of operator decrease which is result in to efficiency gain.
3. Advance tooling used for critical and time consuming operations has shown great impact on efficiency.
4. Before balancing man-hours per machine for assembly is 480 minutes,
   After balancing it became 365 minutes. Which means reduces manufacturing cost of compressor. Result in to overall profit of organization.
5. Kitting material trolley modification done due to this number of trollies per machine are reduced from 3 to 1. And no. of kitter and handling labor also reduced to 1 no.
6. Subassembly work station reduced from 2 to 1 due to lean principles.
7. Number of main working station also reduced and work is completed in 4 workstation only, as compared to 6 in old layout.

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