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MATERIAL HANDLING AND PROCESS IMPROVEMENT USING LEAN MANUFACTURING PRINCIPLES

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ABSTRACT

Global competition has prompted companies to compete on the basis of Quality, Flexibility, Cost and Timely Deliveries. Lean manufacturing appears to hold considerable promise to address these competitive demands. Lean manufacturing was initiated within automotive industry, with the publication of Book "The Machine That Changed the World" (Womak, Jones, Roos,1990) lean manufacturing practices have found acceptance in many industries. In this paper we describe the case where Lean Manufacturing was started. The objective was Process improvements using Lean Manufacturing Principles (Waste reduction, no walking, searching and waiting). Value stream mapping was used to find the scope of improvement in Material Handling. Team also used other lean tools such as 5S, Visual System, Process improvement (Continuous improvement) and Kanban.

Results obtained were material handling time, distance and manpower reduction. This system along with visual system helped, eliminating searching time for items and also reduced waiting time by assembly operator for replenishment of the same. Due to reduction in line stoppages the average output per line improved from 3.4 to 5 panels per line and average cycle time for each panels reduced from 9.1 to 7 hours.

***Key Words**: Lean Manufacturing, Waste Reduction, Material Handling, VSM, 5S, Visual System*

1. INTRODUCTION:

Growth of Nations economy owes their success to their wealth creating sectors, of which manufacturing is a key sector. Looking at manufacturing industry the average investment is three times high then non-process (service) industry, while net value added per capital employed is almost half of non-process sector.*[1]*Looking at current situation firms operating in market has to compete with the firm operating in same market. Firms develop strategies to increase their competitiveness. In order to gain competitive advantage, firms try to reduce their costs, as well as try to differentiate their service or products from their competitors.*[2]*

With the publication of Book *"The Machine That Changed the World"* lean manufacturing practices have found acceptance in many industries. Lean

manufacturing is one of the initiatives that many major businesses in the United States have been trying to adopt in order to remain competitive in an increasingly global market*[3]*.

The focus of the approach is on cost reduction by eliminating nonvalue added activities. The objective of this paper is to use a case-study approach to demonstrate how lean manufacturing tools when used properly, can help to eliminate waste, maintain better inventory, obtain better operational and financial control. One of the Global leading Electric Switchboard manufacturer is used to illustrate approach followed. One of their establishment (Medium Voltage- 4kV to 36kV) in India is taken into consideration.

2. OVERVIEW OF LEAN MANUFACTURING:

"Lean (a term coined by IMVP researcher John Krafcik) *production is lean because it uses less of everything compared with mass production – half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time. Also it requires keeping far less than half the needed inventory on site, results in many fewer defects, and produces a greater and ever-growing variety of products.***"** *[4]*

"Lean manufacturing is a set of operating principles which a manufacturing company may apply to optimize its provision of value to customers. This involves the elimination of waste and the improvement of material flow.[5]

2.1 The rise of lean production

Toyota is credited with being the birthplace of lean production, and their manufacturing philosophy has been evolved from ideas developed in the end of the thirties *[4]*. After the Second World War Toyota and other Japanese organizations suffered from the effects of the war. The resources were straitened and Japan needed to rebuild its manufacturing industry *[6]*. Many of the Japanese companies turned to the western industries to gain ideas and inspiration on how to build up their industry. In the United States, the call was for mass production to satisfy the needs of a large populace. The Japanese market on the other hand was much smaller and investment capital was scarce. With smaller production volumes per part and limited resources, there was a need for developing a manufacturing system that was flexible and uses less resource *[6]***.** The solution was to develop a lean production system, and the production genius Taiichi Ohno at Toyota is said to be the man behind the development of lean production.

2.2 Main Principles of Lean:

2.4.1. Specify Value : What does and what does not create value from the customer's perspective.

2.4.2. Identify all the steps necessary to design, order and produce the product across whole **Value Stream** to

highlight non value adding waste.

2.4.3. Make those action that create value **flow** without interruption, waiting or scrap.

2.4.4. Only make what is **pulled** by the customer.

2.4.5. Strive for **perfection** by continually removing successive layers of waste as they are uncovered

2.3 Value creation and waste:

In Lean Manufacturing, the **value** of a product is defined solely based on what the customer actually requires and is willing to pay for. Production operations can be grouped into following three types of activities:

Value-added activities are activities which transform the materials into the exact product that the customer requires.

Non value-added activities are activities which *aren't* required for transforming the materials into the product that the customer wants. Anything which is non-value-added may be defined as waste.

Necessary non value-added activities are activities that *don't* add value from the perspective of the customer but are necessary to produce the product unless the existing supply or production process is radically changed.

Research at the Lean Enterprise Research Centre (LERC) in the United Kingdom indicated that for a typical manufacturing company the ratio of activities could be broken down as follows:

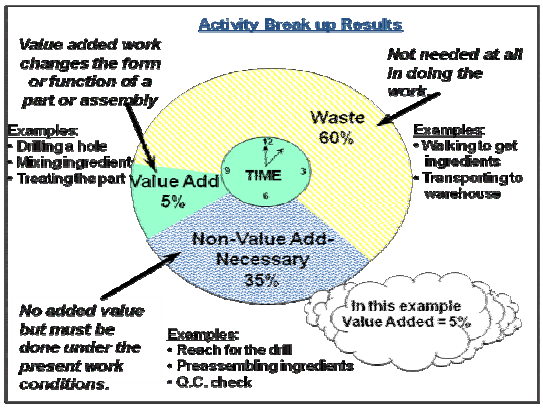


Fig 1. Activity break up

Muda (or nonvalue-added work): Muda is discovered after the process is in place and is dealt with reactively.

Muri (or overburden): It is focused on the preparation and planning of the process, or what work can be avoided by design. Muri can be avoided through standardized work. Muri is pushing a machine or person beyond natural limits.*[6]*

Mura (or unevenness): It focuses on implementation and the elimination of fluctuation at the scheduling or operations level, such as quality and volume. Mura is avoided through the *Just in Time Systems*. It is based on

2.4 Seven types of waste (Muda):

1. Overproduction, 2. Inventory, 3. Defects , 4. Over processing, 5. Waiting, 6. Motion, 7. Transportation, 8. Underutilized People (8^{th} waste included later by Toyota. For detail information of these waste please refer, The Toyota Way, by Jeffrey Liker).

2.5 LEAN MANUFACTURING TOOLS

5s: Focuses on effective work place organization and standardized work procedures. 6th S included is Safety and ergonomics.*[8]*
Cellular Manufacturing: Organizes entire process for a particular product or similar products into a group including all necessary m/cs, equipments.
JIT: *Pulling* all requirements just when they are required.
Kanban: A signaling system for implementing JIT production
Total Preventive Maintenance: Workers carry out regular equipment maintenance to detect abnormalities focus is changed from fixing breakdowns to preventing breakdown.
Setup time reduction: Continuous improvement to reduce setup time on machines.
Total Quality Management: System of continuous improvement employing participative management centered on needs of customers.
Visual Management:

Standard Processes: Standard Process clearly state the content, sequence, timing and outcome of all actions by workers. This eliminates variation in the way that workers perform their tasks. *[3][9]*

3. CASE STUDY (SWITCH BOARD MANUFACTURER)

The firm assembles Medium Voltage Switchboard as well Circuit Breaker for the same, also RMU is assembled. The focus of this study is on one of its Standard Med. Voltage Switchboard assembled in-house.

3.1 Problem Definition:

Previously the manufacturing system adopted by the firm was Batch type production. The constraint with current manufacturing system was that to meet future projected growth the space and manpower requirements will be as shown in Table 1.

	FY 2007-08	**FY 2011-12**	Remarks
Total output (IN + APS)	10000	21000	IN= Panels assembled in house APS = Assembled Panel Structure (Outsourced)
IN panels	4000	8400	@ 40% of total output.
Average working days in a year	280	280	
Avg. output per day	13.8	29	IN panels / No of days
Target per Line	7 **(2 lines)**	10 **(3 lines)**	
Assembly TAKT time (minutes)	60	42	420 minutes available time per line
No. of Lines required/ **(operated)**	2/**(3) $$**	3/**(3 or 4)**	**$$** Two shift operated per day. Two lines in one shift and one line in second shift making total 3 lines.
Total operators for panel line.	63 / 63	74 / **(45)**	74- Actual requirement, 45- Manpower available
Area (Sq. Meter). (Approximately)	15000	21200	

Table 1: Requirements for increased demand

Looking at the table above there are three major constraints to be overcome to achieve the target. These are:

1) Area availability
2) Manpower requirement and availability.
3) TAKT time and panel output.

Analyses of these three constraints were carried out and analysis of table was an eye opener. Even if current Area and Manpower for future growth is sufficient and Takt time is of 42 minutes is achieved, still firm won't be able to achieve the set target, reason being at present firm is unable to reach the set target with sufficient resources. To carry out further analysis team gathered data for Line stoppage and summary of same is as follows. Problem with current system:

1. Material unavailability and missing. (Waiting time)
2. Wrong material delivery to line.
3. Faulty material delivered to line.
4. Non standard material kitting system.
5. Multiple storage of material.
6. Multiple handling of materials.
7. Long distance of material movement.
8. Unsafe handling and assembly process.
9. Lack of visual system (Andon and Kanban) etc.

To make improvement Firm wanted to implement Lean Manufacturing Principle to meet projected market growth till 2012. After initial training in Lean Principles, Lean Manufacturing team was formed. Team consisted employees from all functional departments. One of the group from Planning and Process Engineering (P&PE) was given task of Material Handling and Process Improvements. We will study the work done by this group using Lean Manufacturing Principle.

3.2 Scope of the project:

Reduce the overall handling time, manpower and Distance of Material Handling in Switchboard factory ensuring One piece flow of material

3.3 Objective of Project :

1) Pull Production type assembly layout.
2) Creating Supermarket area near assembly shop. (Purchased part market/ storage)
3) Layout for material storage in supermarket area.
4) Material delivery system (One Piece Flow- FIFO).
5) Visual System (Visual replenishment system, Andon)
6) Manpower reduction for material handling (By **40%)**

7) Material handling system (Reducing handling time **by 40%**)

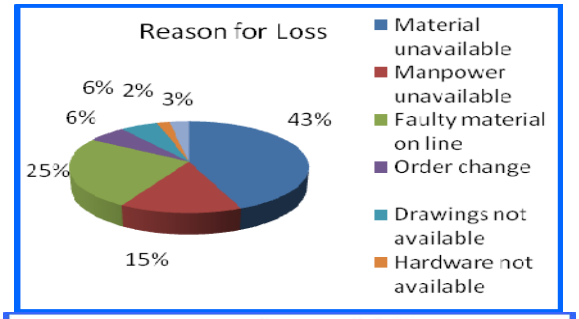
8) Reducing material handling distance.

9) 5S implementation and maintaining the same. Elimination of non- value adding task: reduce transport time “no walking, searching, waiting”

3.4 Data Collection:

Team first wanted to know scope of developing material handling system so they first gathered Output and Cycle time data. After starting lean cell the estimated SMH (Standard Man Hour) /panel is 7 hours. So in each shift approx. 7 panels should be assembled, but actual average output per shift is 3.41, and average cycle time for three lines is 9.1 hours.

Team further gathered data for line losses as shown in **figure 2.** Main reason was material unavailability with 43%. For further analysis data for material unavailability was gathered and summary is as shown in **Fig.3.**



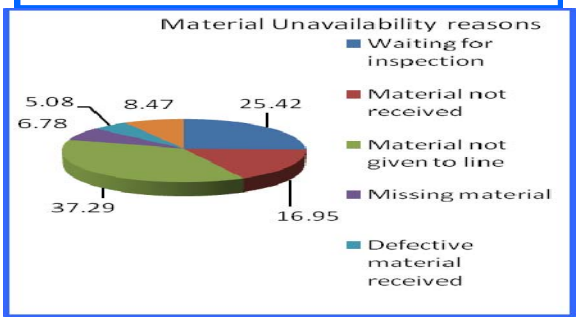


Fig.2 Reason for loss pie chart

Fig. 3 Material unavailability pie chart

3.5 Value Stream Mapping:

To understand how material handling system can be improved Team first carried out the value stream mapping of the process. To carry out VSM process six points needed to be done:

3.5.1. **Select a specific family process :** In this cell it is possible to separate two different handling system: Pallet truck or manual handling work. Also material can be differentiated as Big items, Intermediate items (Kittable), small items (Hardware). Process of handling Big and Kittable item was selected for improvements.

3.5.2. **Understand customer needs :** Making material available at right time, place, quality and quantity with minimum handling. (Delivery at time interval 60 minutes: TAKT time)

3.5.3. **Carry out the process flow:** Each handling process was separated in different stages and cycle time for handling of each item was found out. Also manpower and distance travelled for each item was found out. Summary of same will be shown in Table of VSM summary (Table 2).

3.5.4. **Carry out material flow :** In this step how material arrives and how often goes to Line was studied.

3.5.5. **Carryout the information flow:** Scheduler sends the schedule for one shift in advance. Each responsible logistics engineer has to check for the availability of the material, distribution of the same.

3.5.6. **Calculate working cycle time:** Now it is possible to put all the previous sections together and obtain the current Value Stream Map. Summary of VSM is shown in **Table 2**.

Sr. No.	**Item**	**Logistics**			**Non productive**			**Total**	
		Time **A**	Man power **B**	Dist. **C**	Time **D**	Man power **E**	Dist. **F**	Time min= **A+D**	Dist. mtr. **=C+F**
1	Structures	359	2	2326	158	6	693	517	3019
2	LTC's	208	2	2326	32		441	240	2767
3	CT's	143	2	830	105		100	248	930
4	Earth Switch	143		830	105		100	248	930
5	Kittable Items	168	6	1330	133		700	301	2030
	Total	983 minutes	12	7502 meter	512 minutes	6	2034 meter	1495 minutes	9536 meter

Table 2: Summary of VSM for One days output (21 panels, 7 panels/line)

3.6 Future State Map:

After carrying out current state map it future state map was developed.

1. Reduce material handling cycle time by 40%.

2. Eliminate multiple handling of items.

3. Crate a supermarket area in Lean Cell for Big items (D1 area).

4. Reduce non productive manpower from Lean line and contract labours in Logistics dept.

5. Removal of CT rack from Lean line.

6. Reduce inventory.

7. Develop a Kanban system for Supermarket (D1) area.

8. Visual for schedule display near line for logistics group

4. IMPROVEMENT PROCESS:

4.1 Stage 1: 5S improvements

GEMBA walks are scheduled once in a week. During this period observations were made and team of 2-3 engineers were formed to look after a section of lean cell.

Unwanted items from Commissioning area, Hardware trolleys were sorted out. 30% area was vacated in commissioning area. Stools and trolley used to be kept in haphazard manner. As a second step, floor marking done for each Stools, Trolleys and tables in lean cell. Area allocated for Foundation of LTCs, in D1 area marking done for keeping Big items with Color coding on floor as Visuals for replenishment signals. Shadow board was provided with provision for hardware bins.

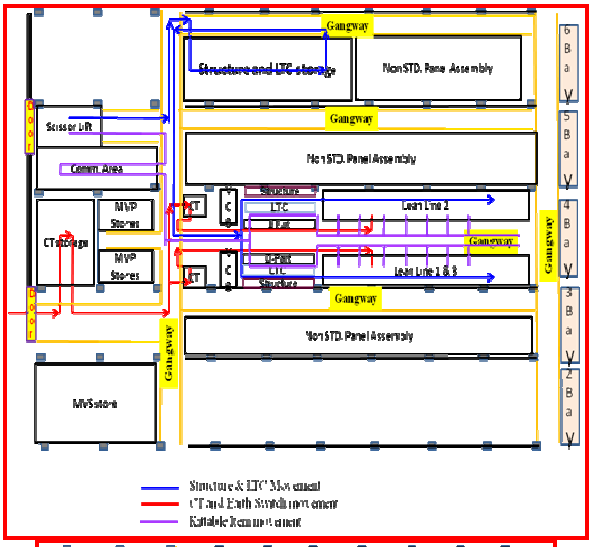
Fig.4 Layout after 5S

Commissioning area, D1 area and CT storage area were cleaned up by removing rejected items and unwanted items. CT storage got one rack freed up. For further improvement on shop floor area which was allocated for each and every item was given names so any new operator can come to know where to store the item.

4.2 Stage 2: Lean Layout and Material Storage

CONCERNS WITH CURRENT LAYOUT:

1. FIFO not maintained
2. Crossing movement of material on shop floor
3. Problem in attaining one piece flow
4. Multiple handling of items (ESWs and CTs)
5. Unnecessary man and material movement (Travel distance).



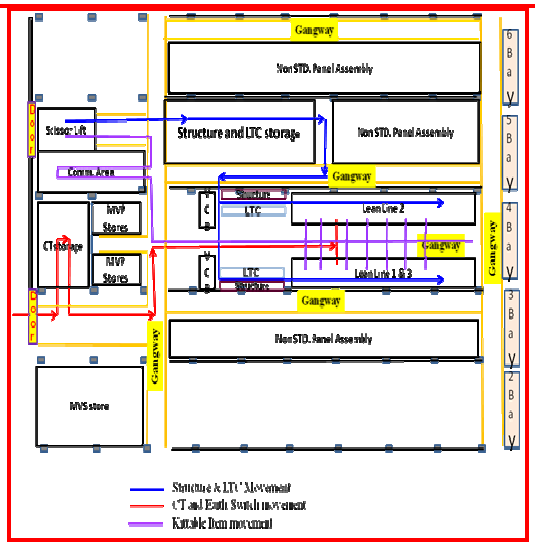


Fig 5. Factory layout before improvement *Fig.6 Layout after improvement*

As shown in **figure.5** Structure and LTC receiving is from 5th bay, storage is in 6th bay and point of use is in 5th and 4th bay. This resulted in unnecessary transport, to reduce it Structure and LTC storage was moved to 5th bay from 6th bay (Refer figure 6). CT and ESW storage rack was removed from Lean cell to reduce multiple handling.

4.3 Stage 3: Material Handling system

Requirements were maintaining FIFO and One piece flow. Team decided implement inventory on wheels for all big items, which will eliminate handling by Pallet trucks. This will help in achieving single piece flow. Also team decided to implement ***Supermarket concept*** near Lean Cell such that inventory of big items for one shift will be kept in advance before start of the shift.

Note: All material handling trolleys are designed taking into consideration material handling principles and ergonomics in handling, loading and unloading of material from same.*[10]* Due to limitation of space the design criteria is not included and saving in travel distance, time and manpower is shown in results summary.

4.3.1 Structure Handling:

Fig.7 Structure handling with BOPT

Fig 8. Structure on Panel

Before Improvement:

1) FIFO not maintained.
2) Fulltime availability of pallet truck and material handler
3) Foundation recycling problem.
4) Loss of two panels per day.
5) Two dedicated material handler required.

After Improvement :

1. Cycle time reduced from 35 min to 14 mins.
2. Travel distance reduced from 164 meter to 115 meter
3. Manpower reduced from 2 to 1.

trolley

4.3.2 CT handling:

Before Improvement:

1) Multiple handling on pallet trucks.
2) Manual lifting near workstation (Fatigue).
3) No identification code resulting in searching time or CT missing.

After Improvements:

1) Identification code panel wise provided on CTs.
2) Trolley for one set of CTs made such that CT will be directly unloaded at the time of receiving.
3) Cycle time reduced from 35 to 16 mins.

Fig.9 CT set panel wise on trolley

4.3.3 LTC handling:

(A) **(B)**

Fig.10 ***(A)****LTC & foundation dismantling,* ***(B)*** *LTC on trolley, elimination of dismantling and Hydraulic truck*

Before improvements:	**After Improvement:**
1) LTC movements on foundation. 2) Handling by Pallet trucks. 3) Difficulty in FIFO maintaining. 4) Unsafe act of dismantling LTC from foundation (Fatigue).	1) LTC on trolley. 2) LTC dismantling eliminated. 3) Eye bolt assembly eliminated. 4) Ease in maintain FIFO 5) Safe working condition.

for handling

4.3.4 Kitting System:

Kitting involves the gathering of all the parts needed for a particular assembly from the stockroom and issuing the kit to the manufacturing line at the right time and in the right quantity.*[11]*

Before improvement:	After Improvement:
1) Insufficient quantity of component 2) Excess quantity of component in D1 area 3) Wrong component 4) More space occupied on shop floor 5) Unnecessary movement of commissioning operator 6) No information of material delivery status.	1) Reduced part damage due to excess handling 2) Reduced operator travel 3) Reduced occurrence of wrong material or material unavailability 4) Removal of kitting tables from D1 area. (10.5 Sq mtr area saving) 5) Material kitting and delivery status board made available. 6) Kitting manpower reduced from 6 to 4.

4.3.5 Kanban System:

After developing supermarket area for big items, team now needed to develop a signaling system for replenishment of these items. The distance between big items storage and D1 area is apart so team needed to develop a Dual Kanban system. *[12.* Still to simplify the process Andon system for replenishment was developed near supermarket and D2storage area. Here green means sufficient inventory, when red is displayed, it's time for replenishment.

Benefits:

1) FIFO maintained
2) Signaling to material handler for delivery.
3) Signaling for logistics to replenish from supplier
4) Order wise stickers provided for better identification.

5.1 VISUAL SYSTEM: The intent of visual control system is that the whole workplace is setup with signs, labels, colour coded markings, such that anyone, in a matter of minutes know what is going on, understand the process, and know what is being done correctly and what is out of place.

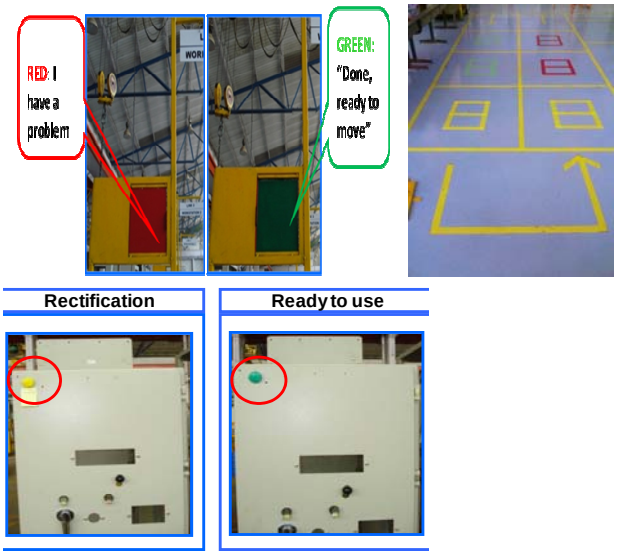
5.1.1 Andon System: When there is concern on line such that operator needs supervisor help then **red flag** will be displayed, similarly when work is complete on particular station and waiting for pulling **green** will be displayed. **Fig. 11A**

5.1.2 Colour marking on floor

Here until green indicates sufficient material available, when Yellow indicates time to replenish, and when red indicates urgent replenishment. **Fig. 11B**

5.1.3 Material Inspection Visuals

Meaning: Green:- Ready to use, Yellow:- Under rectification, Red:- Rejected. **Fig 11c**



(A) ***(B)*** ***(C)***

Fig.11 (A) Andon flag on FIFO rack. (B) Colour visual on floor for replenishment, (C) Material Inspection Visuals

5.2 Shadow board cum Hardware trolley:

Benefits of Shadow board :

1) Area reduced from 12.45 to 6 meter (50% reduction)
2) Ease in maintain 5s for H/w and Shadow board trolley
3) Tools searching time eliminated.
4) Missing of tools eliminated.

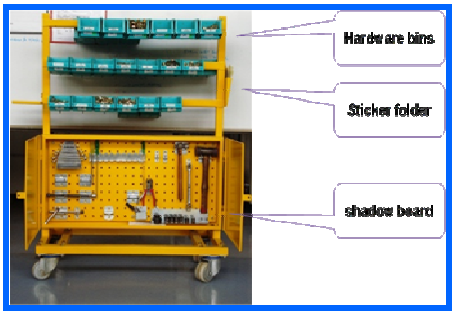


Fig.12 Shadow board cum H/W trolley

5.3 Material Inspection:

Concerns:

1) Uninspected material delivered to line.
2) Less or No time for rectification.
3) Moving rejected material to rejection area and replenishing the same takes time and line stops.

Improvement:

1) Material inspection moved from D1(supermarket area) to D2 (storage area).

Other Improvements includes development of Supermarket concept at the start of shop floor area where inventory of all big items is kept for one shift output. Schedule board is provided on shop floor where schedule for advance two shift and current shift is displayed, also weekly monitoring sheets is displayed for all lines indicating output, cycle time, quality etc. D2 area was created where provision for only 2 shifts inventory is provided.

RESULTS:

Sr. No.	**Item**	**Logistics**			**Non productive**			**Total**	
		Time **A**	Man power **B**	Dist. **C**	Time **D**	Man power **E**	Dist. **F**	Time min= **A+D**	Dist. meter. **=C+F**
1	Structures	204	2	1470	42	3	588	246	2058
2	LTC's	89		1386	11		315	100	1701
3	CT's	75.5	2	1155	15.5		294	91	1449
4	Earth Switch	75.5		1155	15.5		294	91	1449
5	Kittable Items	136	4	550	28		490	164	1040
	Total	580 min.	8	5716 meter	112 min.	3	1981 meter	692 min.	7697meter

Table 3: *Summary of VSM for One days output after improvement*

SUMMARY OF RESULTS

1) Total handling time reduced by 56%

2) Total handling distance or material handler distance reduced by 20% (Only increase in CT and ESW)

3) Looking at daily load on material handler, almost all are reduced by more than 40% .

4) In future when output will be increased from 7 to 10 per line, same manpower will be able to handle the load of handling.

5) If number of lines increases from 3 to 4, only 2 manpower will be increased.

6) Material handling manpower reduced from 18 to 11 (39% reduction). i.e. for future demand in place of 74 operator 52 operator will be sufficient means 7 new recruitments will be required against 29.

7) Total space saving of approximately **100 Sq. meter**. **50 Sq. meter** from D'part area after 5S, **40 Sq. meter** from Supermarket area**, 6.45 Sq. meter** due to new Shadow board cum hardware trolley.

8) Line average output for all three lines had increased from 3.4 to 5.

9) Average cycle time for all three lines had reduced from 9.1 to 7 hours.

10) Material searching time reduced due to storage in sequence and Provision of order number identification tag on parts.

CONCLUSION

Application of Lean Manufacturing in Auto industry. This paper takes a case study of Lean Manufacturing in Electric Switchboard assembly firm. In overview of Lean Manufacturing we had studied the Principles of Lean Manufacturing, types of waste described by TOYOTA, and the tools used by lean manufacturing to eliminate the non value added waste.

Team was given task of developing material handling and process improvement using lean manufacturing principles. First the team carried out Value Stream Mapping of Material Handling system. Using inputs from the same team changed the Line layout and it was named Lean Cell (From batch type production to pull type production layout). Due to this changes material Handling time(56%), distance (20%) and manpower (39%) was reduced. Team developed inventory on wheel concept and made other improvement as part of visual control. Also supermarket concept in material storage on line was developed. Area saving of 110 Sq, meter on line. Also due to new developed material delivery and visual system searching and waiting time were reduced.

As a future scope firm decided to implement same concept for Non Standard panel assembly. From May 2009 firm changed the theme of Project instead of Lean for panel assembly its now Lean Manufacturing for entire factory.

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