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Lean Layout Implementation at Fabrication Plant

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Abstract

The core objective of every manufacturing plant is to cope with the demand and deliver products on time. The production process involves many operations carried out at various stages. To accomplish the production processes and operations successfully each stages has its own challenges and bottlenecks. To reduce these bottlenecks such as reducing motion, waiting time, over processing by incorporating domino effect in various methodologies .This research aims to implement lean layout in fabrication plant to optimize the existing layout for reducing bottlenecks in fabrication of canopies. To overcome bottlenecks, initially for the existing layout required dimensional data of all sections and drawing layout were prepared. To study the existing flow processes for fabrication canopies and their storage methods in racks. The concept of Cellular manufacturing and Just in Time Technique are used to minimize wastage in motion during fabrication of canopies. The method adopted for reducing the waiting waste established by a continuous flow and increase in number of dispatch at the exit. Waste of over processing is minimized by reducing the excess movement and appropriate material handling. Wastage data collected is analyzed by considering elimination approach by rating 1 to 5 .The work efficiency has been examined by considering different processes to estimate efficiency before and after implementation. The work efficiency is found to be increased from 50% to 80% after implementation of lean concept in manufacturing.

Key words: Lean concept, motions, waiting time, over processing, Waste, Space utilization

1. Introduction

Lean manufacturing is a production method designed to reduce time for production and response time to customers and suppliers. It focuses on getting the right things, to the right place, at the right time, in the right quantity to achieve intended work flow by minimizing waste and facilitate to change. The lean manufacturing strategy aims to increase efficiency by eliminating waste, optimizing processes, and cutting costs by focusing on bottom-up, worker-led improvements and a processes. The main principles of lean manufacturing are zero waiting time; zero inventories, internal customer pull instead of push, reduced batch sizes, and reduced process times. Waste directly an impact on cost of the product as waste operations does not add any value hence, customer will not pay for it. Indrajit proposed the lean principles they are one, define value to the product family from customer perspective, secondly, identify all the steps in the value stream for each product family and eliminate the steps that do not create value, thirdly, make the process flow smoother and finally, manufacture as per customer demand only.

Lean Manufacturing is a one of the strategy to reach customer expectations to improve competitiveness in market and to provide greater flexibility, quality, and responsiveness to a production system [1]. Lean manufacturing is an effective management strategy, which helps companies to become accustomed to their value chain for achieving market demand through continuous improvement[2]. The plant layout optimization is a decisive method for achieving greater efficiency in materials handling and reducing manufacturing costs hence, plant layout design is a key strategy for surviving in competitive markets[3,4]. Plant layout modifications are triggered for incorporation of newly purchased equipment in existing production facility layout need to be rearranged conveniently to accommodate the equipment [5,6]. Arrangement of machine on shop floor is a challenging. The most efficient shop floor arrangement depends on requirements of different departments and products within a facility[7].

The studies of layout design in the textile industry for the production flow and the distribution logic of bobbins for the rewinding process in a yarn dyeing factory was carried out and found that a company's productivity might be highly affected by its facility layout. [8,9]. VSM helps to understand visually all value and non-value-added activities during manufacture of a product with its materials and information flows. The current value flow map follow a product's production path from supplier to customer, and also generate flow chart to illustrate possible future situation with greater performance[10]. The different Lean Manufacturing tools and techniques like 5S, Andon, Bottleneck Analysis, Gemba, Heijunka, Hoshin Kanri, Jidoka, Just-In-Time, Kanban, KPIs, Muda OEE, Plan Do Check Act, Root Cause Analysis, Poka-Yoke, Six Big Losses, Value Stream Mapping, Takt Time, Standardized Work, Visual Factory etc. are utilized in lean management [11].

The tools and techniques used to reduce all forms of waste to lower human effort, inventory, cost, and time to produce products while delivering high quality goods.(Radnor et al., 2012). In lean manufacturing there are seven types of wastes like defects, over production, over processing, waiting, transportation, inventory, and motion and also suggested appropriate selection Methods [12,13]. The acceptability and implementation of lean manufacturing in Indian Manufacturing SMEs is analyzed by considering improvement (PI), waste minimization (WM), flow management (FM) and operational performance (OP). The result reveals that lean constructs are significantly related to OP. In the context of Indian manufacturing SMEs, "PI" and "WM" practices have shown a higher level of significance whreras 5S -workplace organization was found to be the most practiced lean tool[14]

The Lean Manufacturing techniques are required across the entire MSME sector like brass, pump and machinery, packaging, auto, textile and garments, so that they can realize the benefits of Lean and invest in sustainable Industry 4.0 techniques leading to Advanced Digital Production (ADP) techniques. The data driven smart manufacturing would enable the MSMEs to maintain competitiveness in the global markets through innovation and internationalization, resource optimization and flexible manufacturing.[8]. The adoption of lean manufacturing practices by different industries to improved customer satisfaction, reduced scrap and inventory for successful organizational changes towards lean organization [13]. The different types of plant layouts like Spine, Product, Process, Hybrid, Star, Loop, U-Shaped, Combined Shaped, Hanger Conveyor, Quick Response, and Flow Based layouts from conventional types to the recent ones are discussed and demonstrated the plant layouts used in garment Industry from earlier times to recent times are also presented to achieve desired output with high quality at lowest cost of manufacturing. [16-17].

Proposed string diagram and implemented lean manufacturing to eliminate the wastes in production flow line using various lean tools which result in reduction in waiting time from 645 min to 462 min, and productivity increased from 50% to 70% and material movement reduced from 283.08 m to 153.92 m[18]. Lean Manufacturing techniques are being implemented and the methodology adopted for the improvements achieved by the SMEs are analyzed[19]. Introduced the lean manufacturing philosophy of continuous improvement to eliminate waste in textile industry and revealed that the use of kaizen and the consistency circles inspire the workers[20].The paper deals with the rejection control, inventory control, waiting time, set time and eliminating non value added time / activities and conclude that lean tools in industries reduce the wastage and increase the productivity[21]. A review was carried out on different manufacturing sectors to study the effect of implementation of lean manufacturing techniques for improving the process and reducing the wastages[22]. This paper focuses on Lean layout implementation at a fabrication plant to improve material placement, better space utilization, Inventory reduction and smoothing the assembly and dispatch process.

2. Existing Layout

The plant carries out the operation of powder coating of different panels of 18 different Canopies making around 550+ subparts.

2.1. Storage Methodology

The storing of parts is not done by adopting group technology or sequencing hence it result into the unwanted movements of stored goods. Uneven inventory levels due to improper inventory count technique for storing of goods. Increase movement distance for collection the good due to non-continuous flow of goods. After completion of the assembly, the components are sorted in multi-story adjustable 72 racks 550+ parts and comprising 21 canopies are accommodated. While sketching the layout of the plant the racks were also plotted and their dimensions in terms of length, width, and height, were also noted. The existing layout, there was no fixed pattern or sequence followed to store the parts results in increased motion and time for procurement of parts before the dispatch. Majority of the parts were stored are loose parts and they are further dispatched through trolleys. The actual photographs of the respective sections are captured and their names are mentioned below the image are shown in Figure 1.

Rack Storage

Storage Method

Base Frame Storage

Rack Placement

Material Inbound

Packaging of Good

Material Storage in Rack

Storage Area

Pre-Treatment Section

Electric DB, Generator

Assembly Section

Secondary Dispatch Area

Storage Rack

Material Dispatch

Paint Section	Panel Painting

2.2. Existing Site Layout

The actual layout is studied and with the help of the measuring devices, the dimensions of the all the sections the plant are measured. The layout as per the measured dimensions is prepared and presented in Figure 2. Visual observation of the existing layout reveals that due to lack of continuous flow throughout the layout and self-paced material running create various bottlenecks. The tremendous unevenness in production output is observed. The scattered movement of material in plant is due to the nature of work place which results in wastage of movement and waiting. A large amount of area is not efficiently used to keep the work in process inventory. Workplace cleanliness are also a serious concern due unavailability of dustbins and rack placement at critical points and at constant distances.

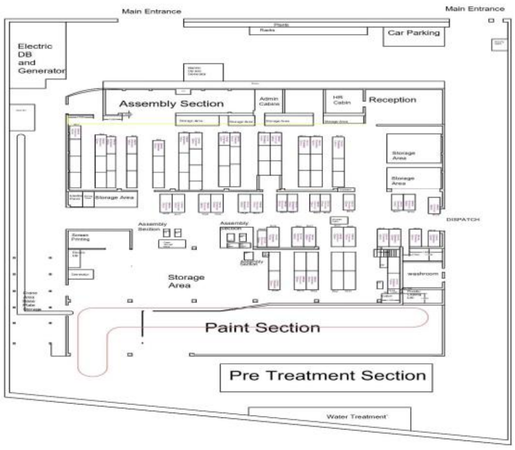


Figure 2: Existing layout prepared

2.3. Process Flow for Fabricated Canopies

In the existing layout, it is observed that there is a random and discrete movement of material within the plant due to a lack of continuous flow. The excess movement led to poor material handling and eventually leading into increased rejection rate. Even the common passage for the dispatch and inbounding of material resulted into delay in either of the operations. The waste of waiting, over processing and movement are prominently observed during existing study of layout. To make a lean layout it is necessary to limit these wastes so that the operations and delivery can be carried out smoothly without running out of stock. The Figure 3 shows the existing flow of the material movement throughout the plant. The flow sequence of parts are, first it enters in treatment section then to paint section to assembly section there after enters to storage section and finally parts are dispatched from the plant. Canopy is a enclosure that is a structure designed to protect from external factors like weather, dust, and noise.

Each of the subparts has to go under various operations before the final assembly. These operations include foam pasting, riveting, hex assembly, hinge assembly, screen printing, sticker pasting, and tapping. After completion of all these operations the parts are either stored as loose parts or assembled and dispatched as per the clients' requirements. These operations are carried out at different tables by different skilled labors. Each operation requires individual work-in-process (WIP) inventory of tools and hardware.

2.4 Waste Evaluation

The waste and clustered areas in the workplace lead to ineffective utilization of manpower, material, time, motion, etc. The above collected data are being analyzed before implementing the Lean Methodology so as to determine the current state or situation of the workplace. Table 1 shows the current level of wastage found at the workplace. Evaluation done on scale of 1 to 5 and rating is varied from'5 - completely lean' and '1- completely traditional.

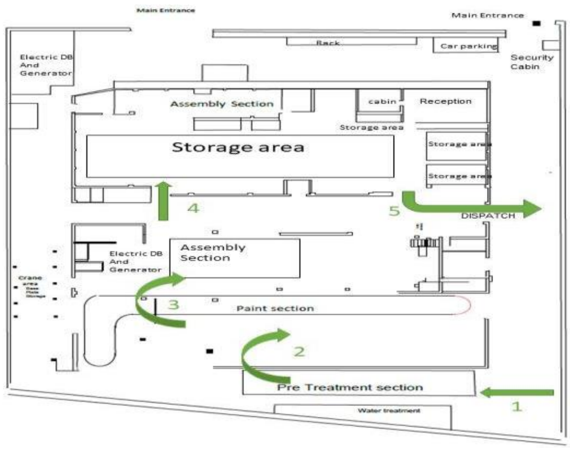


Figure 3: Existing Process Flow

Table 1: Waste Evaluation and Process Efficiency

Sr. No.	Type of waste	Current level	Comments	Processes	Efficiency %
1	Waiting time	3	Due to lack of Continues flow	Assembly	50
2	Motion	2	Scattered part storing	Dispatch	40
3	Transportation	2	Scatter work stations	Material Handling	50
4	Inventory	3	Improvement required in labeling of storage area	Inventory Management	40
5	Defects	2	Due to improper handling of finished goods	Process path cleaning	60
6	Over Processing	3	Due to failure of machine tools over	Working Environment	50
7				Safety	60
8				Working Efficiency	50

3. Implementation of Lean Layout

Before implementation of the lean manufacturing concept, it is necessary to understand the sequence of the operations that is carried out at the plant. After understanding the different operations, it is identified that the invalidity of different works stations in a cluster is one of the prime reasons for increasing processing time. Another reason is bottlenecks in between different workstations thus creating interruption in the value chain. This is due the lack of continuous flow

3.1. Process Flow Optimization for Fabricated Canopies

In the plant there are various canopies fabricated among these canopies majority of them don't require an assembly process. Some of the canopy parts require an assembly process, whereas some parts require finishing after the powder coating operations. The Figure 4 shows the optimized process flow fabricated canopies to reduce the movement and even the lead time to manufacture.

3.2 Optimization of Parts Storage Methodology

All the parts stored in a safe and secure manner so that they can be located safely and easily during the delivery time. The objective is to make inventory tracking of finished goods conveniently for computing the task within a few minutes by any unskilled labor. The motive is to maintain continuous process flow and track parts by considering allocation within the layout. The information collected from industry in regards to part number, part name, minimum stock quantity calculated by using their EPR tool, and the monthly demand for different canopies.

The allocation of the space is carried out in 3 stages for canopy. The space calculations for part storage are carried out using the part dimension with a tolerance of 100 mm on each side of part. The parts with the longest dimension parallel and perpendicular to the ground are placed horizontally and vertically respectively.

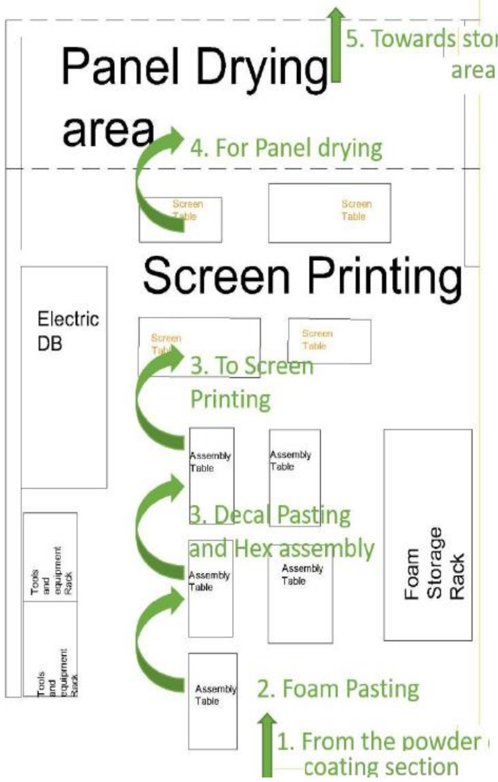


Figure 4 Optimized Process Flow

The height and width of the part remains the same for the pack. Similarly, horizontal parts are placed one above another, hence the height of the part is multiplied by the number of quantities, whereas, length and width of the parts remain same for a pack. The space required for each part is processed using appropriate formulae in excel sheet Screen shot given in Table 2.

Table 2: Excel based Space Calculation Sheet

				Part Dimension(in mm)					Dimension for set (in mm)			Dimension of set with tolerances (in mm)		
Canopy	PART NAME	PART NUMBER	MIN QTY	Length	Breadth	Height	ay of Stack	Part Place-ment in Rack	length	Breadth	Height	length	Breadth	Height
CPM		9096933300	20	1015	550	160	horizonta	Horizonta	1015	550	3200	1115	650	3300
CPM		9096933400	20	1015	550	160	horizonta	Horizonta	1015	550	3200	1115	650	3300
CPM		9096934300	50	460	60	40	horizonta	Horizonta	460	60	2000	560	160	2100
CPM		9096933600	50	550	140	5	horizonta	Horizonta	550	140	250	650	240	350
CPM		9096933352	10	620	160	550	Vertical	Vertical	620	1600	550	720	1700	650
CPM		9096933700	50	520	25	670	Vertical	Vertical	520	1250	670	620	1350	770
CPM		9096933800	50	550	25	670	Vertical	Vertical	550	1250	670	650	1350	770
CPM		9096933900	50	460	25	670	Vertical	Vertical	460	1250	670	560	1350	770
CPM		9096934000	50	570	25	670	Vertical	Vertical	570	1250	670	670	1350	770
CPM		9096933500	20	550	170	670	Vertical	Vertical	550	3400	670	650	3500	770
CPM		9096934400	20	550	230	675	Vertical	Vertical	550	4600	675	650	4700	775

Parts are stored in the wear house multilevel adjustable racks. The grouping of parts can be easily and aligned them as per the demand in descending order in rack. Part grouping is done by considering the factors like monthly frequency of delivery, canopy, and dimension of the parts. The stacking of the parts on different levels is identified based on the dimensions of the parts. The same canopy parts are placed in the same rack by considering the dimension and space available in the rack. The Table 3 shows the placement of the different parts have serial number are placed in appropriate racks assigned with a particular rack number. Table 4 shows the color code system used for grouping of different canopies

Table 3: Placement of Parts in a Rack

Rack Number	Part Serial Number			
	A	B	C	D
1.1	2, 6, 31	3,5,13,15,17,21,23,25,27,28,32,33	167,168,169,171,172,175	-
1.2	12,14,16,18,20,22,24,26	7,8,10,11,19,29,34,38,39,41	176,177,178,179,180	-
1.3	30,35,36,37,40,1,9	166,170,173,174	-	-
1.4	4	4	-	-
2.1	438,439,440,441,442,443,444,445,446,447,448,449,450	437, 451	-	-
2.2	453,454,455,456,458,460,461,462,464	473,474,475,476,459	396	390
2.3	463,465,466,467,468,469,470,471,457	394	402	-

Bar coding and tagging system used for identify parts located in racks and available inventory count of the part. Tags used to understand the consumption of each part and make the replenishment in a convenient manner. By setting predetermined thresholds and triggers for replenishment, the system helps to maintain optimal inventory levels, reducing the risk of stock outs over stocking. The Table 5 shows the bar code and the data base and the quantity of components present in the store.

Table 4 shows the colour code system for grouping of different canopies

Canopy Name	Colour Code	Canopy Name	Colour Code
CP modularity		G 15-22	
XA76ND		G7-15	
CP150/CP180		GA 18-22 IPM	
CPA NEW		GA 18-37	
CPC		XAHS 186	
CPE		GX 2-5	
CPD		GA 7-15 VSD	
CPM		GA 55-90	
CPP60E		GA 55-132 MOD.	
CPS600-200		GA 37-75 VSD	
GA 30-45			

Table 5: Quantity of canopy present in the store

Rack I	Rack Lev	Canopy Nar	Part N	Quant	Barcode
1.1	A	CP MODULARITY	9097555828	10	R1.1A1.9097555828
1.1	A		9097555847	10	R1.1A2.9097555847
1.1	A		9097555872	10	R1.1A3.9097555872
1.1	B	CP MODULARITY	1092900577	10	R1.1B1.1092900577
1.1	B		1092902157	10	R1.1B2.1092902157
1.1	B		1092900579	10	R1.1B3.1092900579
1.1	B		1092900578	10	R1.1B4.1092900578
1.1	B		1092902581	10	R1.1B5.1092902581
1.1	B		1092902545	10	R1.1B6.1092902545
1.1	B		1092902544	10	R1.1B7.1092902544
1.1	B		9097555868	10	R1.1B8.9097555868
1.1	B		9097555869	10	R1.1B9.9097555869
1.1	B		9097555870	10	R1.1B10.9097555870
1.1	B		9097556295	10	R1.1B11.9097556295
1.1	B		9097556294	10	R1.1B12.9097556294

3.3 Waste of Waiting

As all the processes are inline, the delay caused in any one of the operations resulted in domino effect and ultimately resulted into critically low stock level and delay in order to dispatch. To reduce the waste it is necessary to establish a continuous flow and increases the number of dispatch. The material has to travel larger distance during process from starting to till dispatch. The parts which undergoes the through verity of operations across the different sections and tables it results in increase in unnecessary movement which contribute to the increases waiting time and added load on the workers. To solve this concern, it is necessary to adopt the concept of cellular manufacturing and Just in Time Technique. A large amount of distance moved by material during processing and poor handling result in scratches and dents on the finished goods leads to rejection. To resolve the issues, industry use gangway of uniform directions for the ease of material handling and trollies to reach each corner of the plant. To solve the issues related to the waste, the improvement are made in the layout which can aid in the continuous flow. Along with these abet of change in the civil structure such as removing unnecessary walls and tables can also lead increased in the floor space. But there are few limitations such as the DG set, electric DBs cannot be mobilized.

4. Optimized Layout

Figure 3 shows optimized plant layout for reducing waste to maintain a minimum level of inventory.

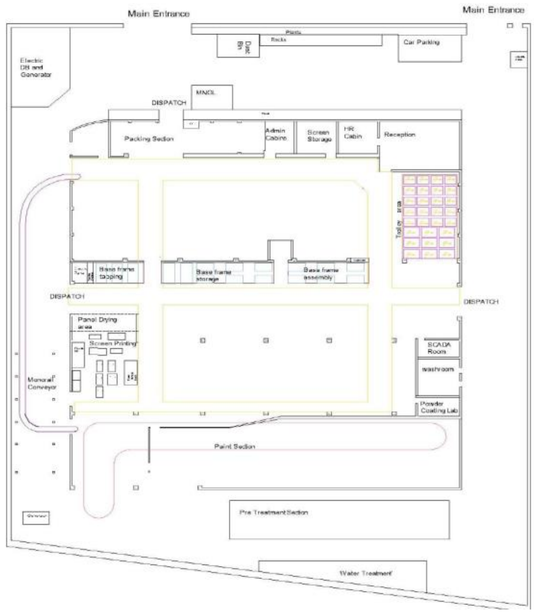


Figure 3 Optimized Plant Layout

The existing layout material dispatch increased to three so, that the material can be dispatched and loaded at the same time to reduce the stagnation of the process chain. The cellular concepts are used for continuous flow of assembly components. The DG set and electric DBs are shifted to a small unit where all the assembly operations are carried out. The generator is shifted to one of the corners of the plant near the paint section. It results in limited movement of the material while the assembly phase. The sufficient space is provided for storing the base plates, racks to store finished goods, and trolleys. The floor space is increased by removing the walls that are not contributing in the process. The increased area is optimally used to accommodate the racks. A monorail conveyor belt is proposed so that the parts that don't require assembly action are directly shifted to the storage section without occupying the gangway continuously. The powder storage rooms previously placed on the ground floor were shifted to the upper level. The room are being used as panel drying after the screen printing. It help the screen-printing to settle and make dust free environment.

5 Proposed Layout

5.1 Proposed Version 1 layout

Layouts is created and reviewed based on various KPIs. The basic objective of the proposed layout is to adopt cellular manufacturing concept witch increases the number of the dispatch points. The designated space for the base frame storage and assembly are provided which lack in the existing layout, whereas previously they are placed within the outskirts of the plant. The predefined location for storing the trolley is the key developments in the layout. The USP of this layout are the availability of accommodating excess number of the racks.

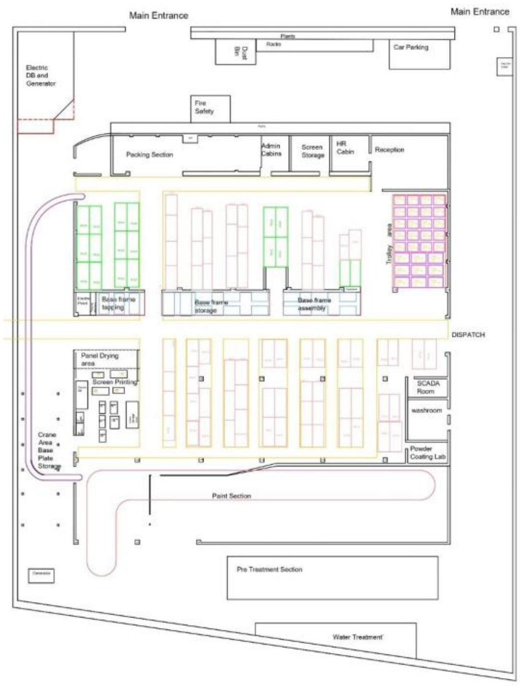


Figure 6: Proposed Version 1 layout

It is observed that the excess moment is required for the trolleys during collection of the finished goods for dispatch. The gangways had dead-ended it result in increases the difficulty in handling the trolleys result in non-continuous flow of the parts.

5.2 Proposed Version 2 layout

To overcome the short comes of the previous version 1 a new layout is proposed by considering the KPIs considered in previous version are kept as it is and few more additional features are added. Apart from extra dispatch points, the cellular manufacturing concept and the other perks such as dedicated place for base frame, assembly and trolleys storages. The major development are made to maintain the concept of continuously flow by interconnecting the gangways to reducing the dead ends. The racks near the dispatch zone are removed for ease of part dispatch.

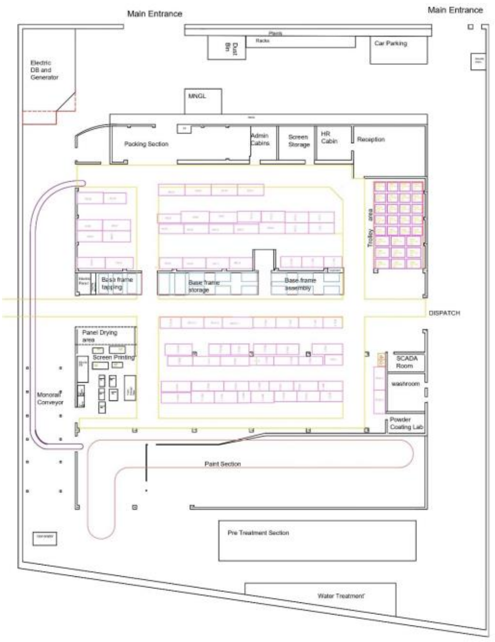
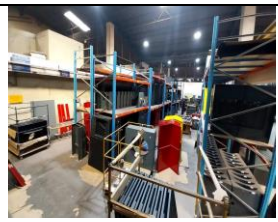
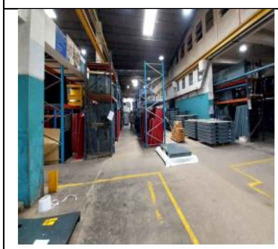
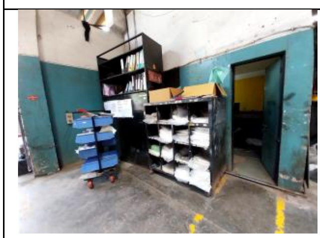


Figure 7: Proposed Version 2 layout

Version 2 help to create the continuous flow and reduce the unnecessary movement, whereas USP of the previous layout is modified by providing extra storage place. The major challenges faced during implementation of layout need to be consider different placement of the rack. The benefits and shortcomings of the both proposed layouts are discussed with industry experts and the faculty to finalize the 2nd proposed version.

5.3 Implementation Layout

A lot of changes are required in the existing layout by considering the civil infrastructure, relocation of different sections to new positions, construction of the new sections, and relocation of the racks etc. which are necessary for implementation of the layout. The first task is to remove the unnecessary walls and railing to clear up the space. New openings are created for the dispatch of the parts and thereafter relocation of the equipment such as powder storage section, the generator, the lift, the dustbin; the electric DB etc. are carried out.

	
Dispatch Zone	Trolley Storage
	
Section 1 Rack Relocation	Section 3 Rack Relocation
	
Section2 Rack Relocation	Visual Assessment Board
	
Dispatch document file and Packing Material	Cabin Assembly Section
	
Screen Printing in Assembly Section	Packing Area and Dispatch

After completion of civil work, the next task is to create a closed cabin for the assembly section. The reason for making a cabin for the entire assembly section is to limit the relocation of the work tables by the worker and the other major reason is to keep the assembly section dust free for foam and screen printing. It is observed that majority rejections occurred due to foam removal or screen printing. Next task is to relocation the previously filled racks by empty racks disassemble them and transit to the new position as per the given sequence predefined is shown in Figure 8. of waste, results cost savings, enhance resource utilization, and improve overall productivity of fabrication plant.

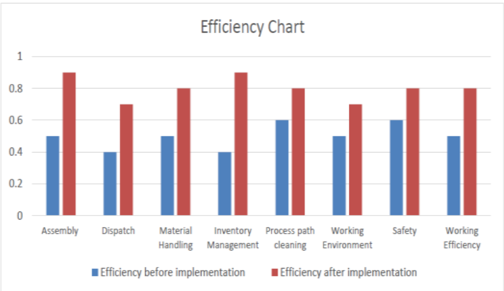


Figure 9: Improvement in Process performance

Enhanced Space Utilization: The lean layout has optimized the utilization of available space within the fabrication plant. Increased Flexibility: The implementation of a lean layout has enhanced the plant's flexibility and adaptability to changes in production requirements improve flow and organization of workstations allow for easier reconfiguration and adjustments to accommodate shifts in demand or product variations.

Visual Management: The use of visual management techniques helps operators quickly to identify the location of tools, parts, and equipment, reducing search time and errors.

Quality Improvement: The lean layout approach emphasizes the identification and prevention of defects. Overall Efficiency and Productivity: The implementation of a lean layout has significantly improved the overall efficiency and productivity of the fabrication plant. Smooth the Dispatch Process: A lean layout ensures that the dispatch area is strategically positioned within the overall layout, allowing for a smooth and uninterrupted flow of products. Kanban cards can represent specific products or orders, providing a visual signal for the dispatch team to initiate the necessary actions.

6. Conclusion

The implementation of lean layout in a fabrication plant offers numerous benefits and improvements in operational efficiency. The lean layout approach focuses on optimizing the flow of materials, minimizing waste, and improved operational efficiency within the plant.

References

[1] Ahmed, S., Chowdhury, S.I., (2018). Increase the efficiency and productivity of sewing section through low performing operators improvement by using eight wastes of lean methodology. Global J. Res. Eng. 18, 44–60

[2] Bai, C., Satir, A., & Sarkis, J. (2019). Investing in lean manufacturing practices: an environmental and operational perspective. International Journal of Production Research, 57(4), 1037-1051. http://dx.doi.org/10.1080/00207543.2018.1498986..

[3] Brahmadeep, & Thomassey, S. (2014). A simulation-based comparison: manual and automatic distribution setup in a textile yarn rewinding unit of a yarn dyeing factory. Simulation Modelling Practice and Theory, 45, 80-90. http://dx.doi.org/10.1016/j.simpat.2014.04.002.

[4] Dongre, A., & Mohite, N. Y. (2015). Significance of selection of material handling system design in industry – A review. International Journal of Engineering Research and General Science, 3(2), 76-79.

[5] Ekasuthan, Balajhi Prasath, M. Shabeena Begam and S. Syath Abuthakeer (2018). Assessment of Lean Manufacturing Practices in Coimbatore Machine Tool Industries. International Journal of Intellectual Advancements and Research in Engineering Computations, Vol.–06(01) pp.788-793

[6] Henao, R., Sarache, W., & Gómez, I. (2019). Lean manufacturing and sustainable performance: Trends and future challenges. Journal of Cleaner Production, 208, 99-116. http://dx.doi.org/10.1016/j.jclepro.2018.10.116

[7] Indrani,. C.Anitha Mary, G.R.Rajalakshmi,. and Mrs. G.Rajamani,(2019) An Empirical Study on Critical Issues of Lean Implementation in Micro, Small and Medium Enterprises with reference to Coimbatore city ,International Journal of Management, Technology And Engineering 9(5), 5445-5456

[8] Indrajit Bhattacharyaa & Anandhi Ramachandran (2019) Lean manufacturing techniques – Implementation in Indian MSMEs and benefits realized thereof, Indian Journal of Engineering & Materials Sciences Vol. 28, February 2021, pp. 89-101

[9] Jia Zhenyuan, LU Xiaohong, Wang Wei, Jia Defeng, Wang Lijun(2011)., 'Design and Implementation of Lean Facility Layout System of A Production Line', International Journal of Industrial Engineering, Vol. 18 No. 5. pp. 260-269. (10)

[10] Kovács, G. (2020). Combination of Lean value-oriented conception and facility layout design for even more significant efficiency improvement and cost reduction. International Journal of Production Research, 58(10), 1-21. http://dx.doi.org/10.1080/0020754 3.2020.1712490

[11] Liu, J., & Liu, J. (2019). Applying multi-objective ant colony optimization algorithm for solving the unequal area facility layout problems. Applied Soft Computing, 74, 167-189. http://dx.doi.org/10.1016/j.asoc.2018. 10.012

[12] Luz, G. P., Tortorella, G. L., Bouzon, M., Garza-Reyes, J., & Gaiardelli, P. (2020). Proposition of a method for stochastic analysis of value streams. Production Planning and Control, 1-17. http://dx.doi.org/10.1080/09537287.2020.18 33377.

[13] Radnor, Z.J., Holweg, M., Waring, J., (2012). Lean in healthcare: the unfilled promise? Soc. Sci. Med. 74, 364–371. https://doi.org/10.1016/j.socscimed.2011.02. 011.

[14] Ridhima Tripathi,(2020) 'Plant Layout – Types and Trends', International Journal of Scientific and Research Publications,. Vol. 1 No. 1. pp. 1-6 (18

[15] Saumyaranjan Sahoo, Sudhir Yadav, (2018) "Lean implementation in small- and medium-sized enterprises: An empirical study of Indian manufacturing firms", Benchmarking: An International Journal, Vol. 25 Issue: 4, pp.1121-1147, https://doi.org /10.1108/BIJ-02-2017-0033:

[16] Shewale, P. P., Shete, M. S., & Sane, S. M. (2012). Improvement in plant layout using systematic layout planning (SLP) for increased productivity. International Journal of Advanced Engineering Research and Studies, 1(3), 259-261.

[17] Zhang, Z., Wang, X., Wang, X., Cui, F., & Cheng, H. (2019). A simulation-based approach for plant layout design and production planning. Journal of Ambient Intelligence and Humanized Computing, 10(3), 1217-1230. http://dx.doi.org/10.1007 /s12652-018-0687-5.

[18] R.S. Barot a, Keyur Raval a, Hardik Beravala a, Amar Patel, Implementation of lean practices in water heater manufacturing industry, Materials Today, 38(5), 2021, 2227-2234, https://doi.org/10.1016/j.matpr. 2020.06.304

[19] V. Ramakrishnan, J. Jayaprakash, C. Elanchezhian, B. Vijaya Ramnath, Implementation of Lean Manufacturing in Indian SMEs-A case study, Materials Today, 16(2), 2019, 1244-1250. https://doi.org/ 10.1016/j.matpr.2019.05.221

[20] M. Mohan Prasad, J.M. Dhiyaneswari, J. Ridzwanul, S.M. Sutharsan A, framework for lean manufacturing implementation in Indian textile industry, Materials Today, 33(7), 2020, 2986-2995, https://doi.org/ 10.1016/j.matpr.2020.02.979

[21] Neha Verma, Vinay Sharm, a Sustainable competitive advantage by implementing lean manufacturing :A Case study for Indian SME" Materials Today, 4(8), 2017, 9210-9217, https://doi.org/10.1016/j.matpr.2017 .07.27

[22] Atul Palange, Pankaj Dhatrak, Lean manufacturing a vital tool to enhance productivity in manufacturing, 46(1), 2021, 729-736, https://doi.org/10.1016/j.matpr. 2020.12.193: