Productivity Improvement through Implementation of Lean tools

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Abstract: *In the competitive manufacturing industry, cost-effective production is crucial for success. A key element in achieving operational efficiency and minimizing costs is an effective facility layout. This paper examines the packaging process for PU foam rolls, employing LEAN tools such as activity analysis, 5W2H, spaghetti diagram, and standardized work sheet among others. By identifying non-value adding steps and areas for improvement, insights were gained. Additionally, optimized machine layout was developed using From/To charts and CRAFT tool. The objective was to enhance process efficiency by analyzing distances, tools, and time for material handling and redesigning the layout accordingly. The results showed significant improvements, including reduced transportation distance (76.2%), time spent (63.3%), operational costs (50%), and increased operational efficiency (164.2%). This study highlights the effectiveness of LEAN tools and emphasizes the importance of production layout in enhancing efficiency and reducing costs for manufacturing companies to stay competitive.*

Key words: process improvement, efficiency, LEAN management, facility layout

1. INTRODUCTION

In production organizations, the efficient utilization of limited resources is paramount. The implementation of improvement methodologies, such as LEAN manufacturing, empowers organizations to streamline their production processes, identify inefficiencies, and eliminate wasteful practices [1]. A well-designed facility creates an environment that promotes efficient operations and facilitates seamless material flow [2]. By strategically organizing workstations, industrial engineers can create a framework that supports and enhances overall competitiveness. By adopting Lean methodologies in facility design, industrial engineers can identify and eliminate various types of waste, such as transportation of materials, excessive movement, waiting time, overproduction, and inventory buildup. This paper aims to outline a proposal for enhancing the efficiency of the PU foam rolls packaging process through a layout redesign. By using activity worksheet, spaghetti diagram, standard work sheet, from/to charts and the 5W2H method, distances, equipment requirements, material transfer times and opportunities for improvement were analyzed. By implementing the CRAFT tool an improved layout was obtained.
The paper was structured in the following way. Section 2 gives an overview of the methodology and methods used for the project. Section 3 describes the case, uses data to present the current layout and explains the proposed improved layout. Section 4 gives an overview and discussion of results.

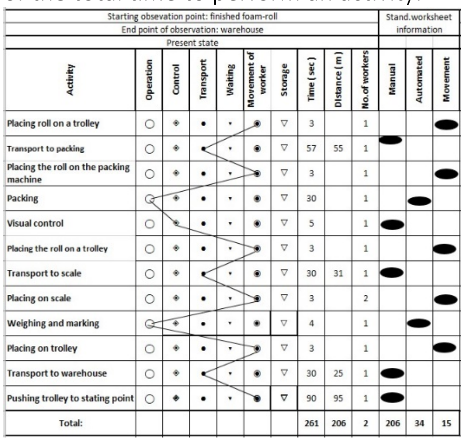
2. METHODOLOGY AND METHODS

The methodology employed in the preparation of this study incorporates both theoretical research and empirical analysis. Building upon the theoretical framework established through the literature review regarding productivity of production organization, the methodology further involved a detailed analysis of the product packaging process with several methods. The activity worksheet as a widely adopted tool for structured representation of the process flow [3] was used for determining the event sequence capturing key information for each operation such as task duration, dependencies, distances and number of workers needed. The spaghetti diagram is an incredibly valuable and effective technique for visual mapping and analyzing the movement of workers and transportation of products [5]. By meticulously tracing and charting the actual paths taken with a spaghetti diagram, a clearer representation of the flow of activities was provided and an identification of losses was more easily identified. When planning activities, defining and supplementing the production schedules, production standards are needed for enabling the fulfillment of quality requirements and delivering safe working conditions with effective use of resources [4]. For this paper a standardized work graph was used for analyzing the ratio of automated and manual work. When in need of a tool for generating ideas and identifying opportunities for change, the 5W2H method is an effective method to apply by asking targeted questions related to a predefined problem or situation. The 5W2H method is built upon five questions that begin with the letter W (What, Why, Where, Who, and When) and two questions that begin with H (How and How often/much). By exploring the answers to these questions, deeper insight into the underlying causes of the problem or the opportunities can be examined with the aim of generating improvement ideas an uncovering overlooked issues [4]. CRAFT (computerized relative allocation of facilities technique) is one of the first tools for computerized layout enhancement and requires the user to specify an initial layout in detail [5]. Flow matrix with the number of units transferred between all departments in a given time, matrix of costs per unit distance when moving between departments, space required for each department should be provided with the goal to design a layout for the process with the greatest reduction of the total cost of transporting the product.

3. ANALYSIS OF THE PU FOAM ROLLS PACKAGING PROCESS

This paper focuses on the packaging process of polyurethane foam (PU foam, sponge) cut and wrapped in a roll which finds application in different segments of the textile industry. The PU foam is originally produced in a rectangular block which is cooled and cut horizontally to obtain PU foam sheets which are then wrapped up in a roll. The roll needs to be packaged in PE foil (for optimizing shipment and ensuring quality), weighed, marked and transported to the warehouse on a hand cart.

The activities included in the packaging process, their duration and number of workers needed for each one are given in the activity worksheet in figure 1. The visualization of the process is represented with a spaghetti diagram in figure 2. After the foam-sheets are cut and rolled up (position X on figure 2) it is placed on a trolley which is operated manually. Each placing of the roll on the cart or on a machine takes on average 3 sec. Transport to the packaging machine (position 3 on fig.2) 57 seconds, covering 55 m. The packing process is automated and takes 30 seconds. The distance between the packing machine and the scale (position 4' on fig.2) is 31 m covered in 30 s. The weighed and marked roll is placed back on the trolley with a forklift and transported to the warehouse (marked W on fig.2) in 30 s which is 25m away. From the warehouse, the worker returns to the starting position (marked X) with an empty cart, covering 95 m in 90 seconds. When performing the activities in this order, one worker travels 206 m and it takes 261 seconds, while two workers are needed for the measurement process in 7 seconds. Also shown in figure 1 is the information derived from the standardized work graph which shows that 13.2% of the overall time for processing one unit is required for automated work, 80.8% for manual work, and 6% for worker movement of the total time to perform an activity.



Starting obsevation point: finished foam-roll / End point of observation: warehouse / Present state										Stand.worksheet information		
Activity	Operation	Control	Transport	Waiting	Movement of worker	Storage	Time (sec)	Distance (m)	No.of workers	Manual	Automated	Movement
Placing roll on a trolley	○	◈	•	·	◉	▽	3		1			●
Transport to packing	○	◈	•	·	◉	▽	57	55	1	●		
Placing the roll on the packing machine	○	◈	•	·	◉	▽	3		1			●
Packing	○	◈	•	·	◉	▽	30		1		●	
Visual control	○	◈	•	·	◉	▽	5		1	●		
Placing the roll on a trolley	○	◈	•	·	◉	▽	3		1			●
Transport to scale	○	◈	•	·	◉	▽	30	31	1	●		
Placing on scale	○	◈	•	·	◉	▽	3		2			●
Weighing and marking	○	◈	•	·	◉	▽	4		1		●	
Placing on trolley	○	◈	•	·	◉	▽	3		1			●
Transport to warehouse	○	◈	•	·	◉	▽	30	25	1	●		
Pushing trolley to stating point	○	◈	•	·	◉	▽	90	95	1	●		
Total:							261	206	2	206	34	15

Figure 1: Activity worksheet

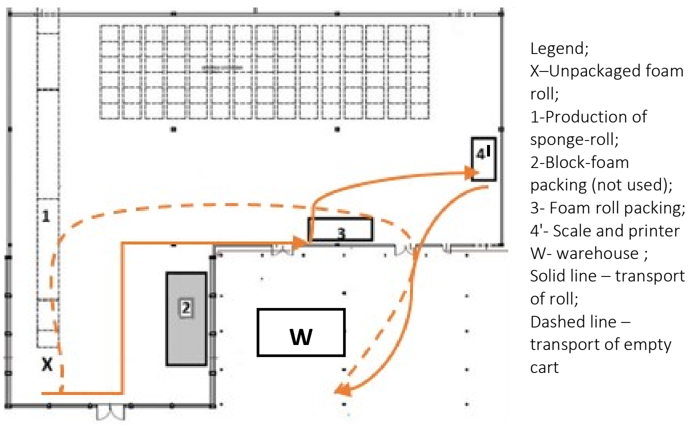


Figure 2: Spagetti diagram

In order to review this process, to discuss the problems and opportunities for improvement, the 5W2H method presented in Table 1 was applied.

Table 1: 5W2H Method

5W2H Method	Question	Answer
What?	What is the problem/opportunity?	- The problem is an inefficient arrangement of machines that imposes unnecessary transporting the product and exposes workers to risky situations while performing work tasks. - There is an opportunity to improve the efficiency of the packaging process by changing the layout of the machines.
Why?	Why does this problem occur?	- Due to the arrangement of machines necessary to perform the tasks
Where?	Where does the problem arise?	- - The problem arises during the transportation of the product for packaging, measuring and marking.
Who?	Who is affected by this problem?	- The employees involved in the process, who collectively spend a lot of time and distance, are affected. - Another process and employees using part of the same equipment. - The organization due to unused potential.
When?	When does this problem occur?	- When transporting the product from one working position to another.
How?	How do we define this problem? (with which parameters)	By analyzing the process by applying: - Chart for standard operations - From/To Matrices - CRAFT tool to improve layout - Time, distance and costs for performing the activities
How (much, long)?	How common is this problem?	- With each delivery of the product, a sponge in a roll

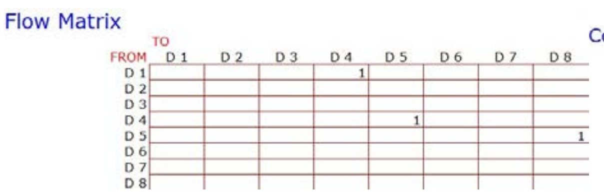
In order to improve the flow of activities by improving the layout in the production enviroment, the CRAFT tool was applied. As explained in section 2, CRAFT is a layout improvement algorithm by which the initial layout is improved by swapping adjacent departments in order to reduce transportation costs.

The production environment is divided into 8 departments, the surface of each department with the number of cells, where one cell has an area of 1 m2. The layout has been corrected manually, to better reflect the real position of departments and machines. In this case, the traditional algorithm with rectilinear movement was used. From/To chart for the initial layout is shown in figure 3 which describes the flow of a roll from the starting point of the cutting machine to the warehouse.

From/To chart for transportation costs between departments shown in figure 4. The cost of transferring one unit between each department is calculated by using the distance data from the activity data sheet presented in Figure 1 and assumptions that gross monthly compensation for the employee is 25,000 den, monthly demand for the product is 500 units, compensation for the worker for one unit is 50 den, distance traveled for one unit is 206m, therefore gross compensation for the worker for one meter is C = 0.24 den/m

According to the formula (1) F=the number of units transported and D=transportation distance, the transportation cost between the departments given in figure 4 is calculated.

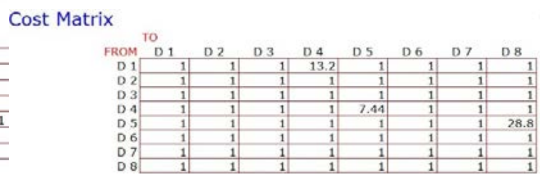
Total transportation cost= $= \sum_{i=1}^{n} * \sum_{j=1}^{n} * F_{ij} * D_{ij} * C_{ij}$ (1)



Flow Matrix

FROM \ TO	D 1	D 2	D 3	D 4	D 5	D 6	D 7	D 8
D 1				1				
D 2								
D 3								
D 4					1			
D 5								1
D 6								
D 7								
D 8								

Figure 3: Material flow



Cost Matrix

FROM \ TO	D 1	D 2	D 3	D 4	D 5	D 6	D 7	D 8
D 1	1	1	1	13.2	1	1	1	1
D 2	1	1	1	1	1	1	1	1
D 3	1	1	1	1	1	1	1	1
D 4	1	1	1	1	7.44	1	1	1
D 5	1	1	1	1	1	1	1	28.8
D 6	1	1	1	1	1	1	1	1
D 7	1	1	1	1	1	1	1	1
D 8	1	1	1	1	1	1	1	1

Figure 4: Transportation cost for a single unit

The tool automatically determines the centroids of the departments and, according to the entered data for the flow of one unit and the costs of transportation, calculates the value of the initial layout shown in figure 5 which in this case is 37.57**.** By replacing the position of the adjacent departments with the same areas, the proposed layout shown in figure 6, with the largest reduction in the costs of transportation and of one unit and the lowest possible value 28.21.

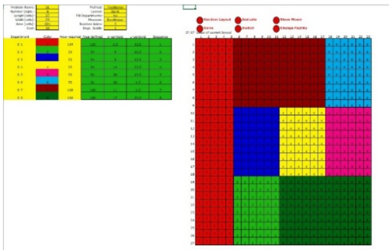


Figure 5: Initial layout visualized by CRAFT tool

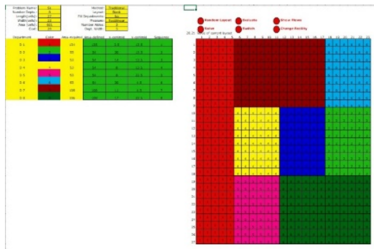


Figure 6: Improved layout

Production of foam roll/ Empty space/Not needed for process/Empty space/Foam roll packing/Not needed for process /Scale and printer/Warehouse

4. DISCUSSION

By analyzing the process of packing the foam-rolls (which includes packaging, measuring, labeling) through activity worksheet, spaghetti diagram, standard operations graph and 5W2H method an opportunity to reduce the waste of transportation of the product through rearrangement of the layout of the machines was observed. CRAFT tool was used for obtaining an improved layout by reducing the transportation distance between the machines thus reducing the transportation cost.

For the implementation of the proposed layout obtained by applying the CRAFT tool, it is necessary to replace the positions of machines 2 (for another process that is not used) and 3 (machine for packing the rolls) shown in Figure 2. It is also necessary to relocate the scale (in Figure 2 marked with 4'), which is part of a transport conveyor system and is needed for weighing another product (block-sponge) and therefore cannot be moved. For that reason, to achieve the proposed layout, it is necessary to provide an additional scale which should be appropriate for the process, position, dimensions and shape of the foam-rolls.

By replacing the layout of the machines and assuming the new distances according to the centroids value obtained from the CRAFT tool shown in Figure 6, the activity sequence remains the same, but the time for performing the tasks and the distance traveled by the worker are shortened.

The total time to complete the activities is 98 seconds and the distance traveled by one worker for one roll is 49 m. The weighing and marking process with the revised layout requires only one worker, unlike the current layout where an additional forklift driver and electric forklift are required.

The change in layout requires changes to the standardized operations graph and a new ration between manual and automated work is established.

Table 2 gives comparison of the times and distances which are traveled by the worker as well as the means used to transfer the roll if the in the actual and the revised layout. It can be noted that in the revised layout there is no need for an electric forklift to position the roll on the scale thus reducing the number of workers involved in the process to one, for manipulating the trolley.

If we take into account the fact that the demand for the foam-roll product is 25 rolls/day, with the data on the time needed to pack one unit given in Figure 1, we can calculate the efficiency of the packaging process for the current and the proposed layout as well as the efficiency improvement by changing the layout with the following formula:

Efficiency Improvement = (New Output-Old Output)/(Old Output)*100

Old output= 261*25 = 6 525 s = 1.8 h - for 25 rolls → 13.88 ~ 14 r/h

New output = 98*25 = 2450 s = 0.68 h – for 25 rolls → 36.7 ~ 37p/h

Efficiency Improvement = (New Output-Old Output)/(Old Output)*100= (37-14)/14*100=164.2%

Table 2: Overview of improvements obtained from the new layout

Type of layout	From/To	Distance(m)	Time (s)	Equipment	Manual (%)	Automated (%)	Number of workers	CRAFT evaluation	Efficiency (units/h)
Actual layout					80.8	13.2		37,57	14
	Machine for rolls-Packing	55	55	Cart			1		
	Packing-Scale and marking	31	30	Cart			1		
	Weighing	1 (in height)	7	E.forklift			1		
	Scale-Warehouse	25	30	Cart			1		
	Warehouse-Machine for rolls	95	100	Cart					
Total		206	261	2			2		
Improved layout					45	38.2		28,21	37
	Machine for rolls-Packing	15	17	Cart			1		
	Packing-Scale and marking	3	3	Cart			1		
	Weighing	/	4	/			/		
	Scale-Warehouse	16	18	Cart			1		
	Warehouse-Machine for rolls	15	10						
Total		49	98	1			1		
Improvement		76,2%	63.6%	50%	Improved balance manual/automated work		50%	9,36	164,2%

5. CONCLUSIONS

The constant changes in the business environment and the demands of the market, impose a need for constant revision and improvement of the productivity of the processes that take place in production organizations. For small and medium-sized enterprises, it is especially important that the existing resources (space, equipment, human resources) are used to the maximum and aimed at greater efficiency during operation.

This paper highlights some of the claims found in the literature regarding the contribution of the optimal layout in the production environment to greater productivity and reduction of operating costs. Similar benefits are noticed when implementing LEAN methodology as a management approach. When using specific methods for analyzing processes and gradual reduction of activities which do not add value to the final product, a reduction of costs and improvement of efficiency can be obtained.

In order to analyze the packing process of the foam-rolls, activity worksheet was first applied, which defined and then explained all the activities in the process along with a spaghetti diagram which helped to visualize the flow of the material and the workers. Standardized work graph was analyzed in order to derive

information regarding the ratio between manual and automated work. 5W2H method was applied for analyzing the process and brainstorming an opportunity for improvement. The CRAFT tool was implemented in order to obtain an improved layout based on the data for the initial layout and process.
By using the CRAFT algorithm a more efficient layout was obtained resulting in 76,2% transport distance reduction, 63.3% time reduction, 50% manpower reduction and 164,2% efficiency improvement.
Further research on this topic should include implementation of simulation models such as DES, ABM and SD for additional experiments with the proposed layout. Also a feasibility study should be conducted in order to ensure that undertaking this change will be profitable.

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