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Applying 5S Lean Technology: An Infrastructure for Continuous Process Improvement

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***Abstract*—**This paper presents an application of 5S lean technology to a production facility**.** Due to increased demand, high product variety, and a push production system, the plant has suffered from excessive wastes, unorganized workstations, and unhealthy work environment. This has translated into increased production cost, frequent delays, and low workers morale. Under such conditions, it has become difficult, if not impossible, to implement effective continuous improvement studies. Hence, the lean project is aimed at diagnosing the production process, streamlining the workflow, removing/reducing process waste, cleaning the production environment, improving plant layout, and organizing workstations. 5S lean technology is utilized for achieving project objectives. The work was a combination of both culture changes and tangible/physical changes on the shop floor. The project has drastically changed the plant and developed the infrastructure for a successful implementation of continuous improvement as well as other best practices and quality initiatives**.**

***Keywords*—**5S Technique, Continuous Improvement, Kaizen, Lean Technology, Work Methods, Work Standards

I. Introduction

IN a highly competitive global marketplace of decreasing profit margins, waste reduction has become an essential element in companies' effort to thrive and in some cases to just survive. Waste (*muda* in Japanese) has a broad meaning that ranges from the unnecessary or excessive use of materials, space, and production resources to any incurred costs that add no value to the product such as overproduction, inventory, set-up, transportation, delay, and rework [1-3]. It is any effort or cost beyond delivering the right product to the right customer at the right time and at the right price. The hidden cost of such wastes significantly contributes to increased production cost, reduced profit margin, and loss of competitiveness. Reducing process waste is the primary mission of lean manufacturing which was started by the Japanese industry, mainly Toyota, in the 1950s [4]. Toyota production system and lean manufacturing in general are focused on pinpointing waste sources and using tools of proven effectiveness to eliminate or reduce waste. Lean defines the major types of waste as: overproduction, over processing, defects, inventory, transportation, motion, underutilization, and delay [5]. *Examples of these wastes in a production facility include:*

- Overproduction: Producing more than demanded or a large quantity of a product before it is needed.
- Waiting time: Machines or workers stop production and wait for materials or others.
- Transportation: The NVA movements of parts, materials, labor, or others.
- Overprocessing (NVA processing): Using highly-skilled operator or machine to operate a job that others with less qualification can perform.
- Inventory: All sorts of product or material accumulation that increases lead-time. It is classified into four types, raw material, work in process, crib, and finished goods.
- Defects: Bad quality level which results from reworking, repairing, re-inspection, and scrapping products or materials.
- Motion: Excess operation movements that often result in tiring workers and lowering their performance.
- Underutilized resources: Labor, machines, spaces, etc.

Lean principles aim at eliminating these wastes through the application of a set of lean techniques. Key lean techniques include just-in-time (JIT), cellular layout, line balancing, error-proofing, quality-at-the-source, 5S, visual aids, and work standards. Other lean techniques include Single Minute Exchange Die (SMED), Total Productive Maintenance (TPM), and Total Quality Management (TQM) Tools [6]. For sustainability, lean techniques application should take place in a continuous improvement "Kaizen" mode [7].

With lean thinking, tasks in production and transactional processes are categorized into value added (VA) tasks and non value added (NVA) tasks. The latest is considered waste in lean thinking and an effort is often put to eliminate or reduce such tasks using lean techniques. A key motivation to invest in such effort is to reduce production costs and increase profit margins while sustaining price competitiveness. Applications of lean techniques have spanned in different sectors of industry including automotive, electronics, and consumer products [8].

Ideally, lean principles are focused on achieving zero levels in the different types of waste. Practically, lean Manufacturing is an operational strategy oriented toward achieving the shortest possible cycle time by eliminating waste. The benefits generally are lower costs, higher quality, and shorter lead times. The ideal characteristics of lean processes include:

- Single-piece production
- Just-In-Time (JIT) pull production
- Short cycle times
- Quick changeover
- Continuous flow
- Zero defects
- Multi-skilled workers
- Low inventory

II. 5S Lean Technology

5S is a lean method and a system of process improvement that is adopted to reduce waste, clean workplace, and improve

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labor productivity [9]. To this end, 5S maintains an orderly workplace and utilizes visual cues to achieve more consistent operational results. As an infrastructure for a culture of continuous improvement, 5S is typically the first lean method which organizations implement to facilitate the application of other lean techniques that improve/optimize process structure and parameters [10].

The 5S components include Sort (*Seiri*), Set in Order (*Seiton*), Shine (*Seiso*), Standardize (*Seiketsu*), and Sustain (*Shitsuke*). Together, they provide a methodology for organizing, cleaning, developing, and sustaining a productive work environment.

The 5S lean technique includes:

1. Sort: Removing wastes and clearing the work area
2. Set in Order: Designating and labeling locations of work tools
3. Shine: Cleaning and improving the appearance of the workplace
4. Standardize: Documenting the work method, using standard tools, and populating the best practices
5. Sustain: Maintaining improvement, controlling work methods, and integrating the 5S's into the culture

In the daily work of a company, 5S maintains organization and transparency which are essential to a smooth and efficient flow of activities. Successful application of this lean method also improves the work conditions and encourages workers to improve their productivity and reduce waste, unplanned downtime, and in-process inventory.

A typical 5S implementation would result in significant reductions in materials and space needed for existing operations. It also would result in the organization of tools and materials into labeled and color coded storage locations such as bins and kits. Such conditions provide the foundation that imperative to a successful implementation of other lean methods such as TPM, cellular manufacturing, and just-in-time production. 5S also prepares the floor and optimizes the process structure to facilitate Six Sigma projects.

The 5S's lead to improved processes in terms of many aspects including:

- Transparent process flow
- Clean workplace
- Reduced set-up times
- Reduced cycle times
- Increased floor space
- Lower safety incident/accident rate
- Less wasted labor time
- Better equipment reliability

III. Application Case Study

This project was executed under the umbrella of Faculty for Factory (FFF) program in Jordan in its 5th cycle. The program facilitates and secures fund for projects executed by university faculty members at local industries. Projects duration is 3 months during the summer term. Faculty members first consult with industry and identify projects in terms of problem-solving and improvement studies. A detailed proposal "diagnostic study" is then submitted to the FFF administration outlining project idea, objectives, approach, and expected outcomes along with industry commitment to the project. Approved projects are funded by FFF sponsors and faculty members work with the industry to achieve project objectives. A detailed final report summarizing the work done is submitted to both the industry and the FFF administration.

This project is aimed at analyzing the workflow and improving workstations at a Prefab factory in Amman. The facility produces prefabricated structures such as portable buildings, homes, offices, and communication shelters. Figure 1 shows an example of the facility prefabricated products.

Fig. 1 Sample prefab product

There are several advantages of using prefabricated buildings, making them a preferred choice over traditional construction. The prefabricated structures are quick to construct and dismantle and can be reused for different projects. They are also stable and earthquake resistant with light-weight and good salvage value.

A. Need Analysis

This project idea has stemmed from an actual need for process improvement at the Prefab facility to cope with the growing demand and the mounting pressure to improve work conditions. Over the last year and due to increased demand, the plant suffered from undefined process flow, excess waste, unorganized workstations, and unhealthy work environment. This has translated into increased production cost, low workers morale, and delays in products delivery. Hence, the project is aimed at defining the production process, removing/reducing process waste, cleaning the production environment, and organizing workstations. 5S lean technique is selected as a methodology for achieving project objectives.

The Prefab plant has been encountering variable production flow and continuous layout changes due to product variation and layout constraints. As a result, substantial time and effort is wasted in changing and setting the configuration of the production line along with causing issues related to flow backtracking, complexity in controlling floor operations, workplace organization, cleanness, and transparency. This has implications on lost resources' utilization or burdening the operations and stressing employees. Hence, there is a need for workflow analysis and a redesign for the plant layout to suit

product variability while maintaining clean and organized work environment and controlled floor operations. Figure 2 shows examples of process waste.

Fig. 2 Examples of waste and on-floor inventory

B. Project Objectives

The Prefab Company is keen on increasing the effectiveness of their manufacturing and assembly operations through a better workflow and an enhanced layout of the workplace. This is essential step in the company's effort toward attaining excellence at all aspects and activities. Hence, this project aims to study the current workflow at prefab facility, pinpoint existing flow issues, and analyze the overall impact on the effectiveness of the production system.From a managerial perspective, the project will work on developing a flexible layout for a streamlined production flow and reduce layout changes and setup costs leading to easier plant management and better floor control. They were less worried about optimizing process parameters (resources, layout, sequence, cycle time, etc.). From a shop floor perspective, this project will organize the workplace and create a better work environment for line workers to improve morale and facilitate the execution of work orders and improve floor communication.Based on the plant state analyses, the project will identify the process and come up with a set of measures to streamline workflow, reconfigure the manufacturing and assembly process elements, and reorganize the workplace. 5S techniques are used attain improvement in the overall process effectiveness.

C. Methodology

A simple yet effective methodology is followed for attaining project objectives. Project scope is defined after touring the facility and tracking the production process along with discussions with plant management, engineers, supervisors and general labor. The project need was obvious to all parties and the project value was found to be significant to the company. The difficult part was how to carry out floor changes and make a tangible difference in the process flow. To this end, this project followed a simple yet practical approach to stir a change on the shop floor, clean the flow, and start a momentum for continuous improvement.

The methodology can be summarized in the following:

1. Observe floor operations at the facility and diagnose current workflow and work organization problems.
2. Identify and develop a structure of the current manufacturing process
3. Investigate workplace organization problems from shop floor observations, labor, and line supervisors.
4. Use 5S techniques to improve existing workflow and process configuration.
5. Discuss improvement measures with plant management.
6. Document analyses and results in formal report and present to plant management.

The main expected project outcome is to improve the overall process effectiveness at the plant. Other benefits include a better organization of workplace and work activities to streamline operations, simplify floor control, and improve workers morale. Implications on the Prefab bottom lines include increasing effectiveness, reducing excessive flow, reducing setup time and cost, and improving the utilization of expensive assets and resources. This is also tied with the employee incentive program to further improve productivity and profitability. The project has started by defining process layout and dividing the plant into 10 production areas. This step was essential to identify layout, define flow areas, and prepare for 5S application at all plant areas. This was followed by conducting a lean and 5S awareness at the facility through meetings and seminars held for plant engineers, supervisors, and workers. Once all are familiar with the project objectives, lean technology, and the project timeframe and work plan, a cleaning campaign has started inside and outside the plant. Cleaning the plant floor and backyard was necessary to clear the aisles, improve the environment, and make a visible change in the work place to both workers and visitors. These three steps made it easy to start the application of 5S approach at the defined areas in the plant. Each area took an average of a week to make a tangible difference. Several meetings were held with plant management to discuss progress and exchange ideas. Special 5S forms were developed to assure sustainability. All project actions were documented and a final report is issued to plant management and to the FFF administration.

IV. 5S Application

It is often simple to talk about how lean approaches work and about 5S in particular. However, the implementation of lean tools on the floor is totally different. This is because 5S is not just a methodology; it is a culture change that involves all parties to drive the organization towards effectiveness and continuous improvement. Thus, we had to first make it clear to all project parties why we are adopting the 5S lean technology. The diagnostic study conducted at the Prefab plant revealed the following issues that collectively call for 5S application in the plant to identify process and improve layout and flow:

- Space is crowded with parts and tools
- Unneeded items are stacked between workers
- Excess inventory on the floor
- Excess items and machines make it difficult to improve process flow
- Equipment is dirty and a collection point for miscellaneous materials
- Needed equipment such as tools are difficult to find

Based on the diagnostic study, the 5S lean technique is adopted for process identification and workflow improvement at the Prefab factory for the following reasons:

- 5S facilitates process definition by cleaning, sorting, and setting in order
- 5S provides the infrastructure necessary for plant-wide improvement
- 5S is essential for streamlined process flow and layout redesign
- 5S is essential for worker motivation and increased loyalty
- 5S is the key for clean production environment
- 5S is essential to deploy safety measures and reducing accidents
- 5S is key to waste reduction:
  - Minimizing waste and reusing waste materials
  - Minimizing effort and time wasted in searching
  - Removing excess material and inventory

It is also worth mentioning that 5S is not a list of action items that has to be reviewed at some interval of time. Instead, it has to be practiced consistently in all times. Thus, a practical step-by-step approach should be followed to make 5S attain a successful implementation.

The followed project steps are summarized in the following:

1. Process structure and identification (layout and flow)
2. Awareness and training on 5S approach
3. Overall plant inside and outside cleanup
4. Applying 5S to 10 plant departments
5. Utilizing checklists for 5S implementation and auditing
6. Waste reduction (less waste and reused materials)
7. Space utilization (clearing main aisle, providing space for reused items, clearing plant floor, providing space for material handling)
8. Cleaner and safer work environment
9. Setting a basis for labor incentives
10. Achieving a better labor morale

The process identification step includes dividing the plant into 10 areas/departments based on specialty and flow. It also includes creating and marking borders for each area and providing access to a marked and cleared main aisle to improve flow and facilitate material handling.

As shown in Figure 3, the plant is divided into the following areas:

1- Woodworks
2- Foam Processing
3- Welding Studs
4- Folding Machines
5- Sheet Metal Processing
6- Doors Assembly
7- Presses
8- Framing
9- Metalwork
10- Storage

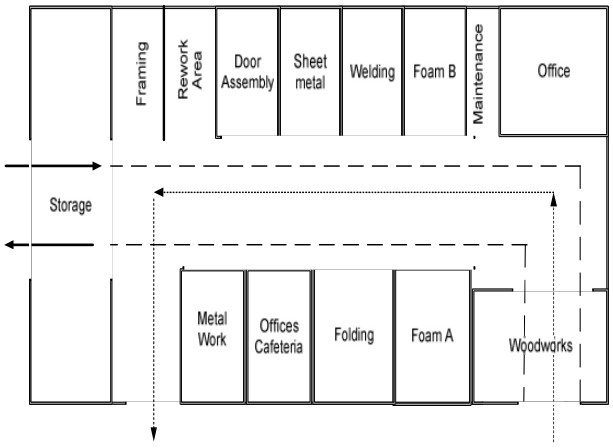

Fig. 3 Layout of work areas at the prefab facility

Initially, there were no clear boundaries to plant areas. It was also difficult to move materials from one area to another. A crane is used to transfer heavy materials and parts from one area to another. Final office structures are assembled in an area outside the plant. Workstations were unclean and flooded with excess inventory, rework, and scrap. The improved layout shows cleared main aisle, no flow obstacles, marked in/out areas, and more space for reusing items and material handling. These plant areas are organized and the main plant aisle is cleared and marked.

After identifying and cleaning the process flow, the 5S was then implemented at the 10 areas of the Prefab facility. An action plan was set and followed as a practical guide for translating 5S method and principles into specific actions that stations operators can take and sustain. This work element presented a great challenge to project team. The team has to work with general labor and stations operators on a cultural change. They have to believe in the actions taken in 5S application in order to make tangible and sustainable changes on the floor. To this end, the team focused the 5S implementation effort on one plant area (woodworks) to create

labor awareness in the 5S method and to provide tangible evidence that can convince labor to cooperate with the changes and believe more in the 5S value and benefits.

The team started the work on station sorting, ordering, and cleaning while operators watching. They start to ask questions on why this work is being done and whether this work is part of a certification program. We explained to workers that this work is simply to clean and organize their workplace, it is not part of any company certification program, and keeping the station clean and organized will be rewarded through an incentive system. as a result, workers start to help in 5S changes at the first work area (woodworks). Area operators were trained on what exactly need to be done to keep the area clean and organized. The 5S procedure was put on a form and posted at the work area.

Figure 4 shows the layout of woodworks area and Figure 5 shows a picture that reflects the results of 5S application to the woodworks area. It is clear from the layout and the actual status of the workstation that the 5S application has resulted in a clean and organized work area. Flow input/output is improved and a cellular layout is adopted to facilitate machines control and supervision. Aisle passes through the area is cleared to allow for easy access of material handling trucks.

Few days later, everybody at the plant noticed that the woodworks area has become different, clean, organized. The morale and the productivity of the area workers have also improved. It was the right time to explain the approach to all and to start a gradual application of 5S at the other plant areas. The work continued gracefully at all other plant areas. A new layout is developed for each area and all 5S's are applied at the 10 work areas. Combined with a drastic clean-up of plant floor and plant outside, the picture starts to be clear one month later. The plant significantly looked different. Some said it is like another plant.

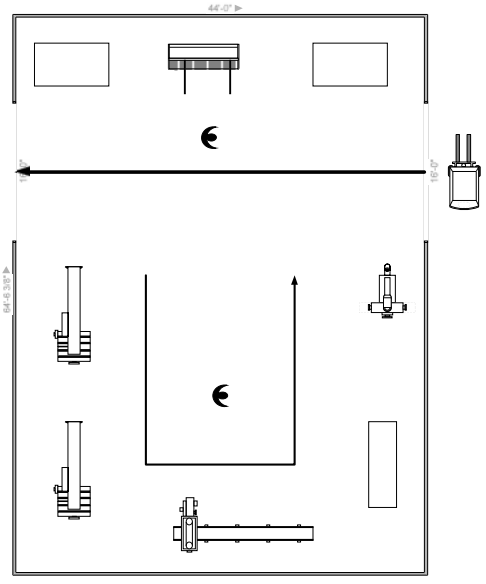

Fig. 4 Improved layout of woodworks area

Fig. 5 5S application to woodworks area

In 5S application to the defined 10 areas at Prefab facility, it was necessary to develop a 5S checklist based on the 5S practical guide discussed earlier. The check list helps identifying opportunities and techniques for 5S successful and comprehensive application.

The project deliverables to each area in the plant is summarized in a 5S table as summarized in the forms developed for each area and a detailed layout is developed for each area. Results collectively revealed a better process flow, a transparent production process, and a cleaner work environment. Specific actions on the floor were taken to save space, create and label storage areas, mark aisles and increase safety, and streamline the flow of production operations.

TABLE I
SUMMARY OF 5S APPLICATION TO WOODWORKS AREA

Prefab Plant 5S Application Summary of Action Items		
Plant Area: Woodworks **Description:** Wood cutting & shaping (mill, drill, saw, bench) **Date:** **Area Supervisor:**		
5S Step	**Action Item**	**Remarks**
S1: Sort	- Classify wooden materials - Red tag unused materials - Dispose process waste - Organize used tools - Put wood boards in holding area	Waste from woodworks fill the floor and unsafe working condition result from wood boards around machines
S2: Set in order	- Create shelves for wooden parts - Store tools on the walls - Label shelves and tools	Shelves are designed to fit types and sizes of wood parts. Milling machine is used from the

	- Reconfigure machines using cellular layout	middle to clear aisle.
S3: Shine	- Clean floor & walls - Clean machines & tools - Mark aisle and workstations - Open ventilation window	Ventilation is necessary to clear machines dust. Marking stations helped in input/output flow.
S4: Standardize	- Create a procedure for 5S and post it at the workstation - Leave 10-15 minutes for checking the first 3 Ss	The procedure is translated to Arabic and posted at workstations.
S5: Sustain	- Create an audit checklist for all 5S actions - Conduct a monthly Audit.	Incentive system uses 5S commitment. Management follow up is essential.

V. Conclusion

This paper has presented an industry application of 5S lean technology at a Prefab factory. Several plant conditions have called for the improvement of the manufacturing process (a combination of job shop and assembly operations). The process flow at the Prefab facility is not streamlined due to the wide variety in product specifications, the growing demand, the push production policy, and the nature of heavy metal and woodwork operations. As a result, the plant has turned into a jungle of dirty machines and excess materials, scrap, and rework spread all over plant floor creating a plenty of flow complications and causing space and production issues. Under such conditions, it was not possible to seek improvement or to run Kaizen exercises and apply quality standard and assurance systems. A project is, therefore, aimed at cleaning, identifying, and streamlining the process. 5S lean technology is utilized to develop an infrastructure for continuous process improvement. A practical 5S methodology is implemented to 10 areas in the plant during the project period of 3 months to clean up the process and improve overall plant operations. At each area, a thorough clan up process is started, a new layout is developed, and all 5S's are implemented using clear forms and procedures. Results showed tangible changes on the plant floor along with improved worker morale and increased productivity. The approach can be adapted to other types of manufacturing processes as well as offices and service processes.

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