APPLYING LEAN CONCEPT IN ASSEMBLY PROCESSES

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Rezumat. *Articolul prezintă conceptul de producție Lean Manufacturing, principalele metode ale sistemului de producție Lean (Just-In-Time, Jidoka, Munca standardizată, Management vizual – Andon, 5S, Verificarea erorilor – Poka Yoke, Schimbarea rapidă a fabricației – SMED, Mentenanța productivă totală – TPM, Harta fluxului de valoare – VSM, Kanban) şi recomandări privind aplicarea acesteia. Sunt analizate principalele caracteristici referatoare la: fabricatie, exploatare, tipul de producție, planificare, diagnosticare şi mentenanță. Unul din obiectivele acestui articol este să-i ofere cititorului informa□iile necesare pentru a cunoaşte mai mult despre posibilitatea implementării Lean pentru o linie flexibilă de asamblare şi a estima mai bine beneficiile obținute ca urmare a implementării.*

Abstract. *The article presents the production filosofy Lean Manufacturing, the main metods of the Lean production system (Just-In-Time, Jidoka, Standardized Work, Visual Management – Andon, 5S, Verification of errors –Poka Yoke, the fast changing of the fabrication – SMED, The maintenance of total productivity –TPM, The map of value flow – VSM, Kanban) and recomandations on its applications. Are analyzed the main characteristics: manufacturing, operating, production type, planning, diagnostic and maintenance. One of the goals of these articles is to provide readers with informational resources for learning more about possible implementation of Lean in a flexible assembly line and the benefits derived from these system conversions.*

Keywords: Lean Manufacturing, Assembly lines, Workstation, VSM, Kaizen report.

1. Introduction

The term lean centers around the idea that the customer purchasing a good or service is only willing to pay for the value added "steps" in making or delivering such a service. Therefore the non value adding "steps" and its associated costs are barred by the manufacturing company, thus reducing margins for the manufacturer.

Lean Manufacturing is "A systematic approach to identifying and eliminating waste through continuous improvement by flowing the product at the demand of the customer." [1]

Lean Manufacturing or Lean is a manufacturing term used to describe a manufacturing, industrial or service operation which operates with little or no type of *muda* (waste), thus making the operation very efficient and only consisting of value adding steps from start to finish, as can be seen in a value stream map. [5]

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2. Lean characteristics and solutions for waste reduction

Organizations that fully adopt lean manufacturing principles can assembly products economically in lower volumes and get them to market faster. In some cases, lean manufacturers can double production at similar or better quality levels using half the time and space, at half the cost, with greatly reduced inventory.

The following nine principles represent the core elements of all lean manufacturing programs: lean equipment, elimination of waste, flexibility, visual factories, error proofing, point of use storage, setup reduction, workplace organization, just-in-time (JIT) production. [2]

The main characteristics of a Lean Enterprise are:

- Integrated single piece continuous workflow;
- Close integration of the whole value chain from raw material to finished product through partnership oriented relations with suppliers and distributors;
- Just-in-time processing: a part moves to a production operation, is processed immediately, and moves immediately to the next operation;
- Short order-to-ship cycles times; small batch production capability that is synchronized to shipping schedules;
- Production is based on orders rather than forecasts; production planning is driven by customer demand or "pull" and not to suit machine loading or inflexible work flows on the shop floor;
- Minimal inventories at each stage of the production process;
- Quick changeovers of machines and equipment allow different products to be produced with one-piece flow in small batches;
- Layout is based on product flow;
- Total quality control. Active involvement by workers in trouble shooting and problem solving to improve quality and eliminate wastes;
- Defect prevention rather than inspection and rework by building quality in the process and implementing real time quality feedback procedures;
- Team-based work organizations with multi skilled operators empowered to make decisions and improve operations with few indirect staff.

Lean means manufacturing without waste. While products significantly differ between factories, the typical wastes found in manufacturing environments are quite similar.

For each waste, there is a strategy to reduce or eliminate its effect on a company, thereby improving overall performance and quality. Waste has been classified into seven main categories as in the diagram below (see Figure 1).

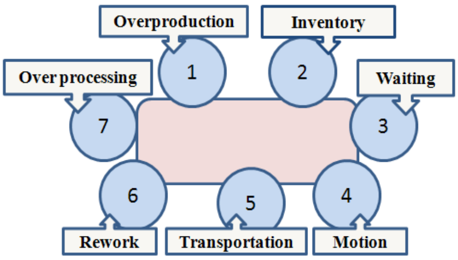

Fig. 1. The seven commune wastes

The seven commune wastes consist of:

1. Overproduction, manufacturing an item before it is actually required. Overproduction is highly costly to a manufacturing plant because it prohibits the smooth flow of materials and actually degrades quality and productivity. The Toyota Production System is also referred to as (JIT) because every item is made just as it is needed. Overproduction manufacturing is referred to as Just in Case. This creates excessive lead times, results in high storage costs, and makes it difficult to detect defects. The concept is to schedule and produce only what can be immediately sold / shipped and improve machine changeover/set-up capability.

2. Waiting, whenever goods are not moving or being processed, the waste of waiting occurs. Typically more than 99% of a product's life in traditional batch-and-queue manufacture will be spent waiting to be processed. Much of a product's lead time is tied up in waiting for the next operation; this is usually because material flow is poor, production runs are too long, and distances between work centers are too great.

3. Transporting product between processes is a cost incursion which adds no value to the product. Excessive movement and handling can cause damages and increase the risk for the product to be deteriorated. Material handlers must be used to transport the materials, resulting in another organizational cost that adds no customer value. Transportation can be difficult to reduce due to the perceived costs of moving equipment and processes closer together. Furthermore, it is often hard to determine which processes should be next to each other. Mapping product flows can make this easier to visualize.

4. Inappropriate Processing, many organizations use expensive high precision equipment where simpler tools would be sufficient. This often results in poor plant layout because preceding or subsequent operations are located far apart. In addition they encourage high asset utilization (over-production with minimal changeovers) in order to recover the high cost of this equipment. Toyota is famous for their use of low-cost automation, combined with immaculately maintained, often older machines [11]. Investing in smaller, more flexible equipment where possible; creating manufacturing cells; and combining steps will greatly reduce the waste of inappropriate processing.

5. Unnecessary Inventory, Work in Progress (WIP) is a direct result of overproduction and waiting. Excess inventory tends to hide problems on the plant floor, which must be identified and resolved in order to improve operating performance. Excess inventory increases lead times, consumes productive floor space, delays the identification of problems, and inhibits communication. By achieving a seamless flow between work centers, many manufacturers have been able to improve customer service and slash inventories and their associated costs.

6. Unnecessary / Excess Motion, this waste is related to ergonomics and is seen in all instances of bending, stretching, walking, lifting, and reaching. These are also health and safety issues, which in today's litigious society are becoming more of a problem for organizations. Jobs with excessive motion should be analyzed and redesigned for improvement with the involvement of plant personnel.

7. Defects, having a direct impact to the bottom line, quality defects resulting in rework or scrap are a tremendous cost to organizations. Associated costs include quarantining inventory, re-inspecting, rescheduling, and capacity loss. In many organizations the total cost of defects is often a significant percentage of total manufacturing cost. Through employee involvement and Continuous Process Improvement (CPI), there is a huge opportunity to reduce defects at many facilities.

3. Case study of a Lean assembly line

An assembly line (see Figure 2), also called production line, is a manufacturing process where interchangeable parts are added to a product in a sequential manner to create a finished product. It's an arrangement of tools and workers in which a product is assembled by having perform a specific, successive operation on an incomplete unit as it passes by in a series of stages organized in a direct line until is completed. [10]

As Lean stated, in a production line (see Figure 2) or in a production flow the previous step won't produce more parts then the next step requires in each *n* workstation ($Ws_1 ... Ws_n$). Machines and equipments may be set up from „groups" of identical machines to assembly line (AL) to meet production requirements. Thus it has been created multiprocess production line.

In this Lean system, independent units (*IU*) are linked with conveyor lines (*CL*) converting many discreete operations into a lean and continuos linear manufacturig cell. [11]

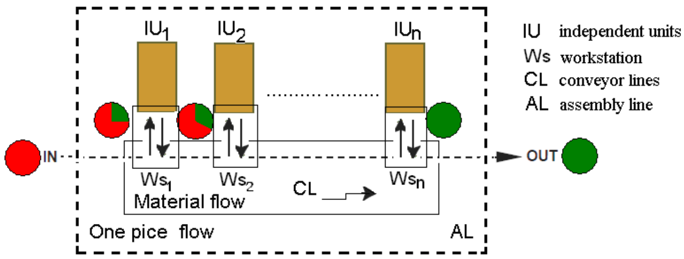

Fig. 2. Model of a Lean assembly line

Even in today's automated environment, skilled workers continue to dominate the shop floor, from material preparation through product shipment. Because assembly tasks and processes are changing with increasing frequency, people and the work they perform at workstations will continue to be critical in a wide variety of manufacturing operations.

When selecting workstations for lean manufacturing environments, the entire use cycle should be considered. Correctly designed and configured workstations can make a significant impact on reducing waste in all the areas.

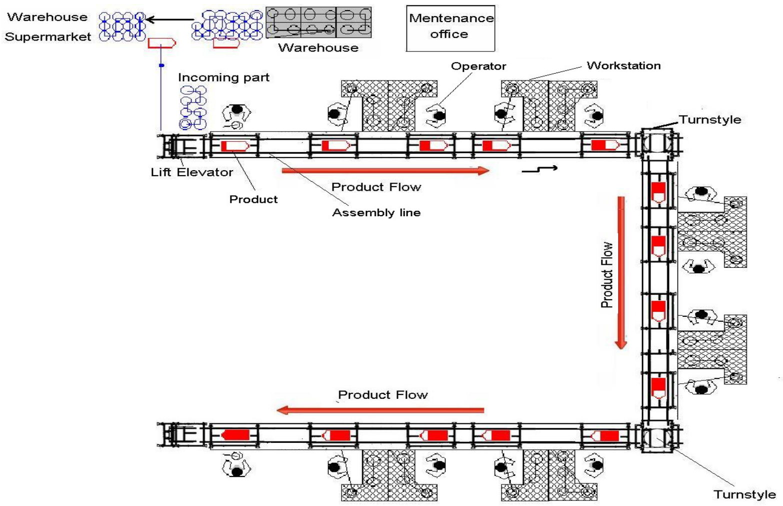

Fig. 3. Lean assembly line

Lean AL (fig. 4) is integrating most of the Lean principels for assembly lines.
Visual factories, visual management give the ability to quickly assess the state of production activity simply by looking around. Clear lines of sight and use of color are two important concerns. [9]
Clear lines of sight are important for spotting production bottlenecks, operator movements, parts shortages and floor inventory issues. Workstations have slim structural profiles and minimal visual obstacles that interfere with observations.
Color is used to identify processes, departments or product lines. The ability to add or change color accents on workstations enables managers to use color for these purposes.
The AL is designed for flexibility. The line is designed to handle demand fluctuations and mixed model production. There is one-piece flow between manual workstations.
One Piece Flow has many benefits. It keeps work in process at the lowest possible level. It encourages work balance, better quality and a host of internal improvements. [6]

Error proofing. Specific instructions are typically provided for setting up workstations based on the task, product or tools to be used. Diagrams are used to show locations of essential tools and materials. Setup personnel are able to set up workstations with minimal opportunity to make errors.
The work area is organized to maximize efficiency, is essential for cycle time reduction and process control. Tools and materials are arranged near the operator according to frequency of use, and they should always be returned to designated tool holders or storage areas. Orderliness results in minimum waste of human energy, while contributing to effective inventory management at the workstation.
Just-in-time production requires that only the needed number of units be produced on demand. This results in smaller lot sizes and greater product variety. Workstations is easily reconfigured and set up so that producing small lot sizes is practical and affordable. [8]
Point of use storage. On the factory floor, "supermarkets" are mini storage areas for tools and materials. They contain just enough parts to maintain production, but without any excess. Materials are located as close to their point of incorporation in the product as possible, typically at the workstation itself.
The processes in this complete Lean AL can range from simple manual assembly to technologically complex. Material flow is downstream and information flow is upstream. The line uses the pull system for material control. The AL incorporates inventory and production control trough kanban, quality assurance, continuous improvement, and preventative maintenance functions. Then the workstations are linked by the kanban inventory and production control subsystem to final assembly.

4. The Major Lean Improvement Tools

In order for lean to be fully leveraged in the eyes of the customer, improvements need to be implemented through the entire value stream and in all administrative processes. This step transforms lean efforts from a cost reduction/streamlining process into a competitive weapon. In the eyes of the customer a fully engaged lean enterprise will satisfy customers better than the competition and market share is taken away from the competition resulting in long-term prosperity.
In a Lean system, focus begins with a value stream map, which depicts all the process steps (including rework) associated with turning a customer need into a delivered product or service, and indicates how much value each of the steps add to the product. Any activity that creates a form, feature or function of value to the customer is termed value-add; those that don't are called non-value-add.
While Value Stream Mapping (VSM) is the key Measure tool of Lean, other methods and their associated tools are needed to achieve the full potential of improved speed. VSM provides a clear understanding of the current process by: Visualizing multiple process levels; Highlighting waste and its sources; Making "hidden" decision points apparent. With this knowledge, we can manage decision points, form a future

roadmap for implementation, and identify opportunity areas. VSM also provides a communication tool to stimulate ideas by capturing critical organization knowledge and identifying locations for data gathering and process measurement.[4]

4.1. Overview step by step of the creation of a VSM for the assembly line

We created a process map from the MRP router information on that value stream. Because MRP routers generally have good data only on value-add steps, but not on the other 95% of the time used, we initially start with a value stream that looks clean (see Figure 4 left). We input the MRP data in supply chain accelerator software to identify the Time Traps.
Walk the process, was the most important step because help us to find out what really happens, and identify both value-add and non-value-add work, such as rework loops, quality inspections, moves in and out of stock (i.e., time that does not appear in MRP), and information flows. I was surprised to find more non-value-add steps in the process than value add. (see Figure 4)

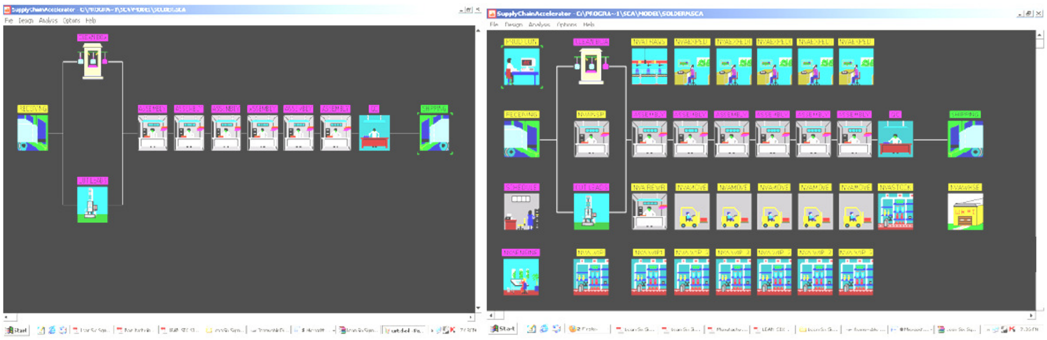

Fig. 4. VSM Downloaded from MRP Router Information and VSM Highlighting the Hidden Factory

The input data for supply chain acceleration software, the setup time, the TAKT time are analyzed. The Time Traps are then sorted on a spreadsheet or displayed in a bar graph. Figure 4 shows the bar graph for the assembly line of an automotive industry supplier, which was the output from this step. The delay time at each Time Trap is calculated, and a recommendation for application of Lean tools is recommended. The Black Belt can input how much improvement can be effected, and the spreadsheet or software will recalculate the delay time.
The VSM simulation shows the chain is only as strong as its weakest link. So as the simulation runs, each point process is observed using the tools such as the 10-second test, the 15 minute observation, the kaizen target report and kaizen event forms, and VSM maps. There are enough materials between both kits to run the simulation building cars continuously for as long as the team requires stabilizing the flow and proving the observations and recommendations.
The VSM Loop simulates the functions of supplier; stockroom; sub-assembly; final assembly; optional detail process; quality inspection; finished goods inspection;

shipping; customer; material logger; planning; purchasing and accounting. Each of these point processes or functional job elements can be the focus of the loop to explore ramifications of various process and procedures on the value stream and flow velocity. For example, assigning market values to components and labor elements allows the accounting function to tally cost metrics for warehouse and buffer inventories, cost impact of rework and stock-outs, and other hidden factory costs in each of the nine simulated flows. [7]

The problem of balancing an assembly line is characterized by a set of n distinct tasks that must be completed on each item. The time required to complete a task is a known constant. The goal is to organize the tasks into groups, with each group of tasks being performed at a single workstation. In most cases, the amount of time allotted to each workstation is determined in advance, based on the desired rate of production of the assembly line. This is known as cycle time. [5]

In an effort to determine how the proposed changes would affect the system a simulation was performed to study the effects of part characteristics, system configurations, and worker assignments on machine utilization and machinist utilization.

For arrangement of tasks to deliver products at the desired cycle time or TAKT we simulate the flows (see Figure 5). The analysis defined the appropriate values for the parameters flow cycle and workforce size that minimized the operating costs of a process running at a determined TAKT.

If no more constraints existed in the manufacturing process, the load chart of workforce requirements per assembly cycle will look like the example in Figure 5.

The workforce would be evenly distributed across the chosen flow time to meet TAKT, and equal volume of work will be assigned to each position. A position is analogous to a workstation for an assembly operation.

We analyzed all interrelations between the process steps and the functional requirements and the production condition (2shifts / day, 6h / shift, 6 brakes / shift, 10 minutes break / hour, 5 working days/week, production rate = 1350 units / day, calculated TAKT time = 6’ 10’’) and we try to balance the work volume between workstations modifying only the parameters and maintaining the actual structure of the assembly line.

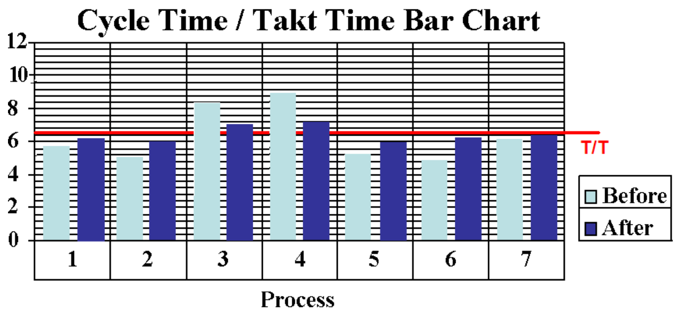

Fig. 5. Line balance chart values before and after optimization.

The line balace will have little impact if they are applied to process steps that contribute little to delay time, costs, customer satisfaction, but with other improvement strategies, is possible to improve the results of Lean methods, if you know where to focus.

In many improvement methodologies, “focus” is largely a matter of making judgment calls about what seems most important at the time. With Lean Six Sigma, focus jumps out at us because of the Pareto Principle, which isn’t just a theory but rather an empirical observation supported by years and years of data on actual factories: 80% percent of lead time delay is caused by less than 20% of the workstations (the Time Traps).

The 80/20 rule is called the Second Law of Lean for Supply Chain Acceleration**,** and it holds true whether the root cause of the delay is variation in times (arrival times, service times), nonvalue - added delays such as machine downtime (or long set-up times), or quality problems (scrap, rework). [3]

Conclusions

The benefits of bringing all facets of the business under the lean umbrella can be significant, unfortunately many companies wait until it is a last resort instead of working proactively to make the shift to the lean philosophy.

Adopting a holistic lean philosophy across the entire enterprise is a path rather than a destination. It requires continual monitoring and incremental improvement within each functional department and throughout all external relationships. Ultimately, an organization’s ability to successfully adopt and extend lean across their entire supply chain requires not only organizational discipline and top level commitment, but also the right technology and the right professional services expertise.

The assembly line model can be a good example that can be used on a suits of simulation softwares like MATFLOW, WITNESS, Optimizer. The next step is to optimizate this model, redesigning the line. Based on continuous improvement used in Lean systems, many „what if“scenarios can be analyzed in a short time.

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