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IMPROVING PROCESS PERFORMANCE THROUGH LEAN MANUFACTURING

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***Abstract*—**The present paper aims to emphasize the issues that are related to Lean Manufacturing system, a method of production organization, and specific for a flexible production system, in this fast response to client demands era. This represents the guarantee for a performant enterprise. The main concepts are presented, the application of these principles, which can be adapted in specific ways and in different contexts, both in industry and in services, as well. It aims to generate a change at the workstation level, to eliminate defects, and to increase the efficiency and ergonomics. By this approach, were presented aspect related to the organization of the production process, and how the production line can be improved by reconsidering the production flow and recalculation the number of operators required to achieve customer order.

***Keywords*—**lean manufacturing, quality, performances, technological flow.

I. INTRODUCTION

LEAN MANUFACTURING is currently the most efficient management system of an organization. The Romanian business environment, found in constant change, requires a fast adaptation to market demands. Through the more extensive globalization process it is understood an increased competition on existing domestic markets, due to new competitors coming from developed countries, and with well promoted traditions regarding quality and manufacturing activities organization. Applying LEAN can raise the company's competitiveness and the availability of internal resources, which can be targeted towards business development.

The concept of "Lean" manufacturing (economical manufacturing, without waste [1]) which can be defined as a set of tools, techniques and ideas that an organization uses to achieve its goals and objectives [2], and from the idea of implementing this concept, is natural the desire of producers to eliminate waste. During this process of implementation the jump was made directly to eliminate waste, and in some cases with success, and they were not few. According to the Business dictionary LEAN Manufacturing is defined as "Doing more with less by employing 'lean thinking.' Lean manufacturing involves never ending efforts to eliminate or reduce 'muda' (Japanese for waste or any activity that consumes resources without adding value) in design, manufacturing, distribution, and customer service processes." [3]

In LEAN everything starts from the concept of value – relative to what the customer is willing to pay and to have his requirements satisfied. Therefore the first step in applying Lean is to identify the value in the organization, which determines the value stream map covered by the product or service requested by the customer. Value stream map includes all components of a process necessary for the product or service requested by the client, from concept to launch phase and from order to delivery. Value stream includes the activities that process information related to product realization, and actual activities of processing materials for the physical realization of that product. Lean production refers to a new dynamic process of production development, covering all aspects of industrial operations (product development, manufacturing, human resources organization, and customer services), including also customer – supplier networks, process led by a systemic set of principles, methods and practices. Over the time were identified three main problems that can occur in a production system: Muda (waste), Instability, and Mura (variability), these being the causes that led to system performance decrease and that negatively impact the cost and quality provided.

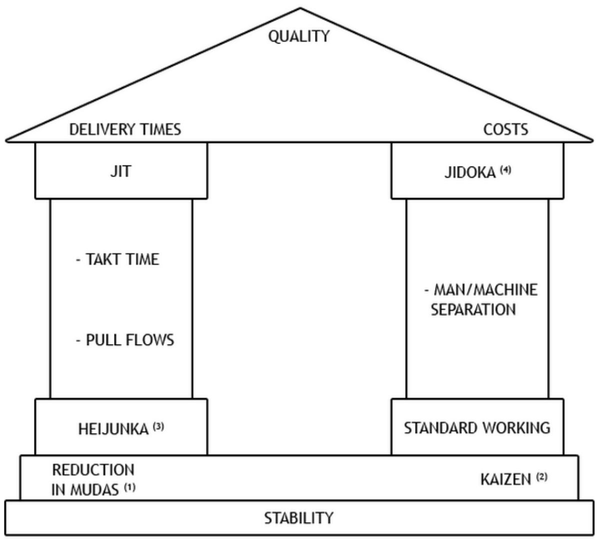

Fig. 1. Lean Manufacturing House [4]

Where: (1) Waste, (2) Continuous improvement, (3) Sequencing, (4) Stop and notify anomalies.

The Lean house, as shown in figure 1, is the symbol used to explain the coherence and harmony of the Lean system, based on a stable foundation - “stability”, having defined clear objectives in terms of short reaction times to customer demand, reduced costs and a high quality for products assured.[4]

The key principles of lean production are perfect quality from the beginning, minimizing losses by eliminating activities that do not add value, continuous improvement, flexibility and long-term relationships with customers and suppliers.

Lean model focuses on the evolution process and continuous adaptation to changes, and is not only a technologically idealized level of organization and work.

II. Case Study

A. Research assumptions

The research was made on a SMT line with which electronic printed circuit boards (PCB) are produced (ex. telecommunications, automotive, medical, etc.). A circuit board manufacturing SMT line includes the following processes: printing - printing boards with solder paste, placement - component placement on pads with existing paste, reflow - their passage through the oven, process by which component stick to the board. The maintenance of all machines that are involved in this process is done by a clear schedule: weekly, at two weeks, monthly and at six months, depending on the requirements. For that are practiced all three types of maintenance: preventive, corrective and palliative.

For the research it was considered a product, which we noted with P1. Our analysis on a 5-week period found that on a monthly production of 5863 pieces, quality problems occur on a number of boards. It was found that one of the major problems that lead to defects is the long distance that the PCB has to go along the process flow to get to the finished product stage, namely 178 m. In the first phase we proposed the distance to be reduced by 30%, meaning that the maximum distance that has to be traveled by a PCB to be 125 m.

The constraints that were imposed in the beginning were: SMT lines and wave cannot be moved; otherwise other board’s production will be affected. The share of other products using such equipment is much higher, about 70%.

To identify the best solutions were analyzed 5 different workstations arrangement with pros and cons for each of them. In order to determine the optimal solution the interval weighting method was applied. For grading was considered a scale from 1 – insignificant, to 5 for very important considering the five criteria, namely ergonomics and environment, number of touches, occupied space, how the moves are made by operators (to be more effective movements made by the operator must be done counterclockwise). For each proposal was made a drawing of the future site for easy scoring by criteria. In table I the results were centralized.

TABLE I
Weighting method on the Interval

V		EE	NoT	S	LA	AC	P
	Wg	3	3	2	2	1	
1	**s**	4	5	3	4	1	**42**
	wts	10	15	4	12	1	
2	**s**	3	5	4	4	5	**45**
	wts	9	15	8	8	5	
3	**s**	3	5	4	4	1	**43**
	wts	15	9	10	8	1	
4	**s**	5	5	4	4	5	**50**
	wts	12	15	10	8	5	
5	**s**	5	5	4	3	3	**46**
	wts	10	15	12	6	3	

Where: EE – ergonomics and environment, NoT – number of touches, S – space, LA – line access for CHO, AC – anti clock wise turn.

After analyzing the variants was found that the most effective is the proposal number 4. This proposal was implemented, making the necessary moves.

B. Production flow optimization

A second stage of the research was to optimize the production flow. For this was taken into account the capacity of the line, on the machine with the highest production time and customer demand. To achieve optimization were considered: the takt time and the cycle time, understanding the actual process flow, establishing the optimal location of the line, and the necessary amount of PCB’s in line, to sustain production.

Takt time is defined as the rate of production that has to be done for a specific product considering the request. In other words, takt time is the frequency with which the customer wishes to receive goods. This takt time allows allocating on the appropriate number of lines and stations so that customers receive products on time.

To determine the takt-time equation (1) was applied.

$$T = \frac{TTA}{TCD}, \tag{1}$$

Where: TTA – total time available, TCD - total customer demand

Cycle time is the time range measured in seconds, in which is ending cyclically an ensemble of operations. Is measured through timing for the effective operation of equipment and the handling time for a specific workstation.

To determine the cycle's time measurements were made at different points in time, were eliminated minimum and maximum values and perform arithmetic mean of the remaining values, finally obtaining the corresponding value.

The production line for which the optimization was performed can be seen in table II.

TABLE II
PRODUCTION LINE CONFIGURATION

	Wave	Press Fit	Wiring	Test area
D	6155	6238	4725	10058
TD	527310	552825	595350	552825
TT	89.95	93.05	132.3	57.71
NE	1	1	6	6
TTL	89.95	93.05	793.8	346.27

Where: D – demand, TD – available time, TT – takt time, NE - number of equipments, TTL – takt time per line. Our analysis found that the production line is not well balanced, thus some operators have been busier than others. Due to the huge mix of different boards, on the analyzed line the Takt Time was needed to determine the critical area on each side. As we considered critical areas Wave, Assy, Wiring and Testing area.

After Takt time was calculated the number of people necessary to achieve customer demand can be found. In Table 3 is presented the determination of the number of operators in critical areas.

TABLE III
NUMBER OF OPERATORS IN CRITICAL AREAS

	CT	TT	NO
HL	129	89.95	1.5
Touch-Up	67	89.95	0.77
Press Fit	210	93.05	2.36
Assy	189	93.05	2.13
Wiring1	1008	793.8	1.32
Wiring2	1008	793.8	1.32
Wiring3	1008	793.8	1.32
Wiring4	1008	793.8	1.32
Wiring5	1008	793.8	1.32
Wiring6	1008	793.8	1.32
Test 1	546	346.26	1.64
Test 2	546	346.26	1.64
Test 3	546	346.26	1.64

To have a better control over the amount of PCBs in the line and buffers between workstations, the pull method was used, also for the line to work linear.

The decrease of the number of boards that were in various stages of production WIP - work in progress, meaning reducing costs that were in materials stored in various stages of the line: in front of the wave from 431 boards to 198 boards, which is a 77% improvement, in the face of assembly from 402 to 201 boards, is an improvement by 50%, from 413 boards in front of wiring are 207 boards, is an improvement by 70%.

WIP (work in progress) represents all materials in various stages of production or raw elements (electronics boards carried out in the research) not functional finished products.

WIP can be the raw material, semi-finished or finished products. This will cause to increase the operating costs, and manufacturing time.

Extra WIP in the line can occur if: previous work produces more than the next workstation can absorb, resulting in stocks between stations (eg. tests cannot handle the number of input boards, having for that well-established times) trial errors not detected, so the cards will not be stopped in time (plates will result in rework).

Due to the diversity and large number of boards that must pass through critical areas it was established to group the products according to the workstations these must pass.

Thus were formed two flows, both flows are balanced in terms of the number of boards that need to be made and the types of stations required.

As a result of this division, there are resulting two separate production lines.

The two lines have the same configuration, but was increased the number of boards that can be processed in one shift, resulting in a pull system (occurs only and when the customer wants) and the decrease of the existing WIP.

The planning process for the products will be based on the flow where they belong. In Table IV and V are the values obtained for the two flows.

TABLE IV
THE NEW CREATED FLOW 1

	W	PF	W	T	S	HP
D	2867	3203	2867	2615	830	1859
TD	527310	552825	595350	552825	552825	552825
TT	193.15	181.25	218.07	222.01	699.77	312.33
NE	1	1	4	2	0.5	0.5
TTL	193.15	181.25	872.30	444.03	349.88	156.16

TABLE V
THE NEW CREATED FLOW 2

	W	PF	W	T	S	HP
D	3289	3036	1859	2685	347	1724
TD	527310	552825	595350	552825	552825	552825
TT	168.36	191.22	336.35	216.20	1675.22	336.67
NE	1	1	2	2	0.5	0.5
TTL	168.36	191.22	672.71	432.40	837.61	168.33

Where: W – wave, PF – press fit, W - wiring, T - takaya, S - spektrum, and D – demand, TD – available time, TT – takt time, NE - number of equipments, TTL – takt time per line. (Also for table III and table IV)

To calculate the optimal amount that is required to be done in line, a standard WIP has to be calculated. WIP standard represents the optimal quantity of boards required in front of each workstation so that any station will not be pending, and the machine with the lowest processing time to work without stopping. The WIP standard was determined for each critical area by applying the equation (2).

$$WIP(before.WAVE) = \frac{Cycle.time}{Takt.time} \qquad (2)$$

So,

- WIP standard before Wave:

$$WIP(before.WAVE) = \frac{Cycle.time}{Takt.time} = \frac{15 \times 60}{75} = 12\,pcs.$$

- WIP standard before Press Fit (PF):

$$WIP(before.PF) = \frac{Cycle.time}{Takt.time} = \frac{15 \times 60}{70} = 13\,pcs.$$

- WIP standard before Wiring:

$$WIP(before.Wiring) = \frac{Cycle.time}{Takt.time} = \frac{15 \times 60}{135} = 14\,pcs.$$

- WIP standard before test area:

$$WIP(before.Test) = \frac{Cycle.time}{Takt.time} = \frac{15 \times 60}{330} = 94\,pcs.$$

Thus, for the line optimization were created two separate flows, defining products that must pass the flow 1, and the ones which should pass by flow 2, the two new lines were designed to be balanced and it was determined the optimal amount of boards that need to be in front of each workstation in critical areas, to achieve the customer's request.

III. CONCLUSIONS

This paper represents a research on how it is organized the production process for electronic boards production and the ways in which the placement can be optimized in a production line, the production flow, the number of workstations and operators to carry out the pieces required by the customer. For the research the whole process has been analyzed when the client launches the demand, how are procured materials, the actual process of production of the board from the raw materials stage to the final product delivery to customer. Optimization is presented considering Lean concepts that apply in all multinational plants.

On the analyzed production line are made many final assemblies. Due to a huge increase in demand, the line must be rebuilt for the new product quantity. The research aimed at changing a workstation to eliminate defects, to increase the efficiency and ergonomics of the workstation.

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