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Vol: 2, Issue: 1

Material Science and Engineering with Advanced Research

The Benefits of Lean through an Analysis and Improvement of an Existing Production Line

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Article Type: Research, **Submission Date**: 11 April 2017, **Accepted Date:** 18 April 2017, **Published Date:** 9 May 2017.

Citation: Gerasimos I. Siasos, Georgios I. Skodras, Evangelos Gkanas, Kostas Hrissagis and Sophocles S. Makridis (2017) The Benefits of Lean through an Analysis and Improvement of an Existing Production Line. Mater. Sci. Eng. Adv. Res 2(1): 15-24. https://doi.org/10.24218/msear.2017.23.

Abstract

The main aim of this research work is to analyse and improve an existing production line by applying the right lean manufacturing tools and techniques. In nowadays, most of the companies around the world use lean methodology at all levels within a company, but more especially at the production line.

First of all, a literature review of lean manufacturing will be conducted. The starting point of the literature review is the history background, the definition and why lean is necessary in the world of manufacturing. The second part of the literature review is about the lean manufacturing tools and techniques. Then a lean assessment guide is defined and finally the implementation plan of lean.

The second part of this research work is referring to a case study. The author visited an existing company where examined the production line from the raw materials to the shipping of finished goods. After detailed analysis, the recommended improvements have to be presented by suggesting an implementation plan. The final stage is to list all the benefits which the company will join after the implementation of the recommended improvements.

Introduction

In nowadays the competition between the companies is in a very high level, because the aim of each company is to retain the highest position in the market place. The most successful way to earn this position is by earning the customer's satisfaction.

The products are manufactured by several methods in production lines, where the raw materials converted into finished goods. This article is focused on these production lines in terms of how to improve them by applying *Lean Manufacturing Techniques.* From a general point of view, the basic rule of *Lean* is to remove waste (or *muda* in Japanese). Waste can be defined as everything that does not add value to the finished goods.

The term and first application of Lean introduced by Henry Ford and his association at Highland Park (Detroit), in 1913. They focused in the potential of flow in terms of how to reduce the amount of effort required assembling a car by 90% less effort. Hence, they took a decision to set up the assembly line into continuous flow with no "fitting" of parts. The next evolutionary step made by Taiichi Ohno and Toyota Automotive Company, after World War 2. Initially, Taiichi Ohno was the person who determined and analysed the 7 types of waste. Also, Ohno used to work for 25 years on Lean Principles and how to implement them at the production line of Toyota. In 1973, after the oil crisis, many companies tried to turn into Lean and learn from Taiichi Ohno and Toyota.

Since nowadays, many companies around the world turned into Lean and join Lean benefits. During the last years, many companies came face to face with the economic crisis and some of them announced that they may be bankrupted due to this crisis. So, the question is if Lean Methodology may help those companies to avoid or to escape from the economic crisis.

Definition of Lean

The reason that led the Engineers to develop and apply *Lean* in the Manufacturing World was to find an antidote to *waste* (or *Muda* in Japanese). Waste can be found in many different departments of a company, but the aim of Lean is to eliminate this waste as much as it is possible. The definition of Lean can be stated as *"A Manufacturing philosophy that shortens the time line between the customer order and the shipment by eliminating waste"* [1].

The need for Lean

Lean Manufacturing is necessary to be applied in all departments of a company, because one sector may affect the other sectors. Hence, the first step before applying any lean techniques is to analyse the seven main types of waste, as they described below:

Overproduction: Overproduction appears within a production line when a product finishes in less time rather than it was required and in higher volumes. One of the main disadvantages occurred by the overproduction waste is that the company needs to spend extra time and space to store the finished goods. In some cases, overproduction may affect the quality of the products or the finished products may be affected. This is because overproduction happened due to pressure around the production line. Furthermore, overproduction leads to high inventories and the result of this is to lead in discouragement and poor communication of the employees. However, Lean has the solution on all the above problems occurred by the overproduction waste. The magic word, is *Kan Ban.* The basic principle of Kan Ban system is to allow the work to move forward only when is needed, or only when the next work area is ready to receive it. In other words, make exactly the required amount, no more, no less, Just In Time and in good quality [2].

Waiting: Waiting means that the delivery of finished goods is not on time or there is a delay in the production line and the product is not finished on time. According to John Bicheno, "Waiting is the enemy of smooth flow". Sometimes, the reason that occurs waiting, is the bottleneck because the cycle time of a process is much higher comparing with the cycle times of the other machines in the production line. So, the next process has to wait until the "bottleneck" task finished. Lean suggest as a solution to this problem, to create supermarkets before the "waiting" process [2].

Processing: The ideal process schedule is to use the smallest machine but without affecting the quality of the product. The reason for this, is that small machines are helping more in the layout of the production line. Also, they do not require enough time to start, they do not need many operators and they do not consume so much energy. Another advantage of small machines is that they can be replaced easily, without costing a lot of money to the company. This helps the company to follow and apply new technology at the production line [3].

Transportation: Unnecessary movement of materials around the factory may affect or damage the product. A very useful example is the fall of an electronic device, where it may have not any visible damage, but it may have an internal fracture. So, a small non visible damage caused by transportation can lead to the increase of the cost, delay on delivery and rework is required to fix the product. Another significant element of transportation, is handling. According to John Bicheno, "Double handling is a waste that affects productivity and quality". Also, long distances between the recourses or the departments lead to poor communication between the employees. The recommended solution to this type of waste is to design a Value Stream Mapping [2].

Motion: Motion is correlated with the motion of the employees. For instance, if an operator has to do more than one tasks, where every task is taking place to a different machine, then the machines have to set up ergonomically at the work place to avoid poor productivity and unexpected motion by the operator [1].

Inventory: Inventory is the waiting of the products or materials before or after a process. The main disadvantage of this type of waste is the increase of lead times. So the product will not be delivered on time. The antidote to "Inventory" is to apply Just In Time technique [1,2].

Rework: Rework or waste of defects, which have two subcategories. The one is the internal failure where it includes those products need to be reworked or they characterized as scrap, or they are delayed. The second subcategory of waste of defects is the external failure which covers the warranty, repairs and field service. The main problem with the products need rework, is that in most cases the damages occurred in the product cannot be seen by the operators. Hence, the inspection department is responsible to check the quality of the products before they reach the market place [2,3,5].

Lean Manufacturing Tools and Techniques

In all or in most sources of waste, lean has the right tools to correct or remove the unnecessary tasks or equipment with the aim to add value to the product. The most important tools and techniques are described below as an answer to the seven types of waste.

Total Productive Maintenance (TPM): Total Productive Maintenance prevents the machines from breakdowns, because a suddenly breakdown of a machine affects direct the quality of the product, the productivity, the cost, the time wasted to fix the problem and in the worst case the whole production line stopped. The last decade, most of the companies turn into TPM in cooperation with Total Quality Management (TQM), with the aim of preventing all the non – adding value tasks. Total Productive Maintenance has three aspects, which are, *Preventative Maintenance, Corrective Maintenance and Maintenance Prevention* [2,6].

Poka Yoke (Fail Safe): PokaYoke introduced by Shingo after World War II and means mistake proofing. This tool of Lean Manufacturing is related with the quality of the products; where the errors have to be inspected before defect the products. This can be achieved by fitting inexpensive devices before or after the machines, so they can "catch" the errors before becoming defects on the products. These devices can be physical, mechanical or electrical which they can do a complete automatic inspection without the effort of the operators. But the operators have to act when they receive a signal from these devices [4,6].

5S Methodology: 5S Methodology is a cornerstone of Lean Manufacturing because it is direct related with the housekeeping within a company. 5S stems the initials of the five Japanese words, *Seiri, Seison, Seiso, Seikets* and *Shitsuke*. But these words were a little difficult for someone to understand the meaning of them, so another version is available for Western people. This version called CANDO and consists of the following words: *Cleanup, Arranging, Neatness, Displine and Ongoing improvement*. Generally, is a methodology for organizing, cleaning developing, and sustaining a productive work environment [4].

Single Minute Exchange of Die (SMED): Single Minute Exchange of Die is focusing in conducting more setups in the same amount of time. So, by reducing the setup or changeover time into half, a cell or a machine is possible to conduct two setups in the same amount of time. SMED has three basic steps, the segregation of the activities, the conversion of internal activities into external activities and the simplicity of tasks [6].

KanBan Production Control: The main purpose of KanBan is to ask for a product or task only when it is needed. KanBan can be divided into two main categories. The first one is "Product KanBan". With this type, whenever a product is called for from it is simply replaced. If there is no call, there is no authorization so there is no production. The second one, "Generic KanBan" authorize feeding of work centers to make a part, but do not specify what part is to be made. The part is specified via a manifest or a "broadcast' system" [6].

Visual Controls: Visual Controls referring on how to make improvements in the activities – issues and performance status through taking measurements on the shop floor. Another aim of visual controls is to make visible the hidden problems [5].

Continuous Improvement: Continuous Improvement is a management philosophy which is based on the employees' new ideas and suggestions. The benefits of CI are the improvement of productivity – quality and the increase of customers' satisfaction.

Cellular Manufacturing: Cellular Manufacturing is focusing to increase the mix of products but at the same time eliminating the waste. This can be achieved by rearranging the facilities and group them into cells. According to Goddart, CM can be defined as a *"process of bringing together machinery and workstations that work on the same parts or products. The process is often equated with group technology, but technically, CM is the linking of machines and operations to produce a part, whereas group technology is primarily concerned with the production of like parts, grouped by design*" [6,7].

Just In Time (JIT): The basic rule of JIT is, "*Make every action, every investment, every second, and every person count. Eliminate anything that does not contribute, and where we are done, to it again – better and then once more – ever better*" OR *"A system for producing and delivering the right items at the right place in the right amounts"* [6].

Standardization of Work: Standardization of Work was one of the first assignments of Taiichi Ohno at Toyota Motor Company. The main aim of work standardization is to ensure that each job is well organized by setting up standards for each job. Ohno believed that the standardization of work must be prepared by the operators. According to Taiichi Ohno, standardization of work consists of three basic elements, the cycle time, the task inventory and the standard inventory [5,6].

Lean Manufacturing Assessment

Lean Manufacturing Assessment or "Gap" Analysis is a self – evaluation methodology which is used in specific areas of the organization to identify the areas that need improvements. The starting point of the assessment is to quantify the current level of progress related with the following criteria: team involvement, training, workplace organization, quick changeover, Total Productive Maintenance (TPM), quality, visual controls, order leveling, material movement and flow manufacturing. Generally, the assessment team has to answer in two very important questions. The first question is, "Where are we?" and the second question is, "Where we hope to be?" Actually, LMA is not used to set targets or to stretch the goals, but is a methodology to compare the current state with the expected state of the organization, or to measure the overall performance of the organization.

The overall assessment is helping the assessment team and the managers to ascertain the sections of the organization which have low score and recommend the right Lean tools for improvement.

The following pie chart shows the sections which have to be assessed by the team or the manager.

It is divided in three sections, the Just In Time (involving the order leveling, the material movement and the flow manufacturing), people (considering the training and team involvement), and the manufacturing excellence (includes the visual controls, quality, TPM, Quick changeover and the organization's workplace) [6,7].

Case Study

Company Profile

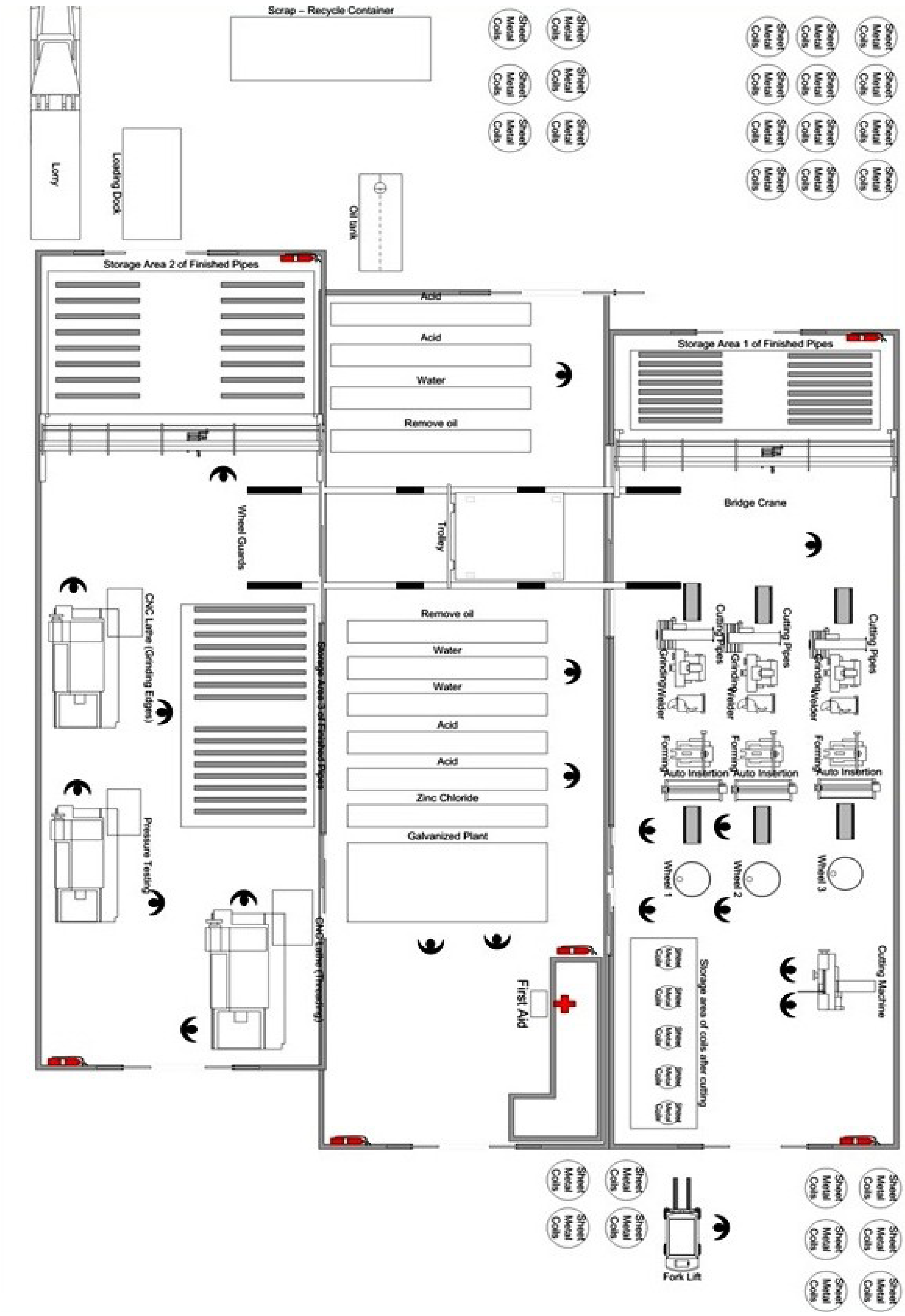
The company is located in an industrial park within the city of Etoliko, Mesologi in Greece. The main advantage of this location is that the industrial park is approximately in the middle of three very big ports, which helps the company for the incoming and outgoing transportations. The company manufactures steel and galvanized pipes for the steel construction projects and water supply, respectively. The management of the company consists of eight people and the shop floor employees are nearly twenty.

The company receives sheet metal every three months, because they use only ships for the transportation in order to save cost, so the order is coming in big batches. Then the sheet metal is stored in the peripheral area as there is no space inside the buildings. In the first building, there are three production lines which are responsible to manufacture steel pipes. The third line installed after the year 2000, where the company introduced the galvanized pipes. Two of the production lines are always in operation and the third one is starting to operate only if the demand from the customers increased. After the production lines, there is a small storage area and a trolley to transport the pipes to the galvanized plant or to the bigger storage area.

The production line is operating for ten hours a day, from 07:00 in the morning since 17:00 at the afternoon. The target of the company is to manufacture 25 tons of steel pipes per day (or 4000 pipes). During the last three years the above target never reached, so the finished goods are not being delivered on time and the customer's complaint about this matter. But, as the competition in the area is very low in manufacturing of steel pipes, this works as an advantage to the company which did not lose any of the customers, instead the profit increased.

Please refer to Appendix 1 for a Top View of the Company.

Appendix 1: Top view of the company



Drivers for Change

The author of this research work visited the company where firstly had interviews with the managers, short discussions with the employees and take his own measurements at the production line. So, the drivers for change are listed below:

Programming Logic Control (PLC) shutdowns in a monthly rate.

Monthly maintenance of the machines can be covered only by the supplier of the machines, who is located in Athens (300km away).

Overproduction.

Unnecessary transportation.

“Bad” storage or raw materials.

High Inventories before or after the machines.

Supplier can ship raw materials only every 3 months.

Customers never received their orders on time.

Current State Analysis

Value Stream Mapping

The definition of “Value Stream Mapping” can be stated as: ”all the actions (both value added and non-value added) currently required to bring a product through the main flows essential to every product: (1) the production flow from raw material into the arms of the customers, and (2) the design flow from concept to launch” [2,6].

The initial step of value stream mapping is to draw the current state map where is represented all the material and information flow as they are at current state. First of all the assessor needs to take into consideration the customer’s order and then collecting all the relevant data from the supplier to the end customer [7].

The goal of the investigated company is to manufacture 25 tons of steel pipes per day. During the examined days the production lines manufactured 2 types of pipes, the gray steel pipes and the galvanized pipes. After 10 days of taking continuous measurements, the average total output was nearly at 18 tons/day. Hence, the company never reached the target of 25 tons/day. After several calculations, the average daily total loss in galvanized pipes was at €4,600 and in gray pipes €28,000.

The current state map shows the cycle time (sec), the changeover time (sec), the machine availability (%), the quality pass rate (%), the observed inventory (pipes, the observed inventory (time) and the inventory (before and after machines) for every process at the production lines. Also, current state map must have the values of lead time, value added time and the Takt time. Lead time is the latency between the initiation and execution of a process, value added time is a summation of cycle times only and Takt time specifies the time required completing a pipe with the aim to meet customer’s requirements.

Please refer to Appendix 2 for Current State Map.

Yamazumi Boards

Yamazumi Board is a chart of Takt time over the cycle time foe each process. The vertical bars represents the cycle time of the processes and their balance with the Takt Time. If one or more processes are not in balance with the Takt Time, then these processes can lead into enormous inventories and problems within the production line [6].

Please refer to Appendix 3 for Yamazumi Boards.

Future State Mapping

It is prerequisite to define the areas or processes where they are not in balance with Takt time or the adjacent processes before drawing the future state map. In our case it is clearly visible that (a) there are high inventories in many resources, (b) the cycle time for process is not scheduled to be in balance with Takt time, (c) and the lead time is very high for both of the production lines [6,7,8].

Hence the right tools and techniques of Lean Manufacturing must be choosing to lead the assessment team to draw the future state map. The following list shows the Lean principles required for the examined company:

Continuous Flow: At the current state map it is clearly visible that continuous flow appears only between the auto insertion and cutting processes. This is because the machines set up to the same cycle time. But, there is no continuous flow in the first and last processes. Therefore, the need of creation continuous flow at all stages is necessary. Also, continuous flow can be combined with other lean techniques, like pull systems or FIFO lanes.

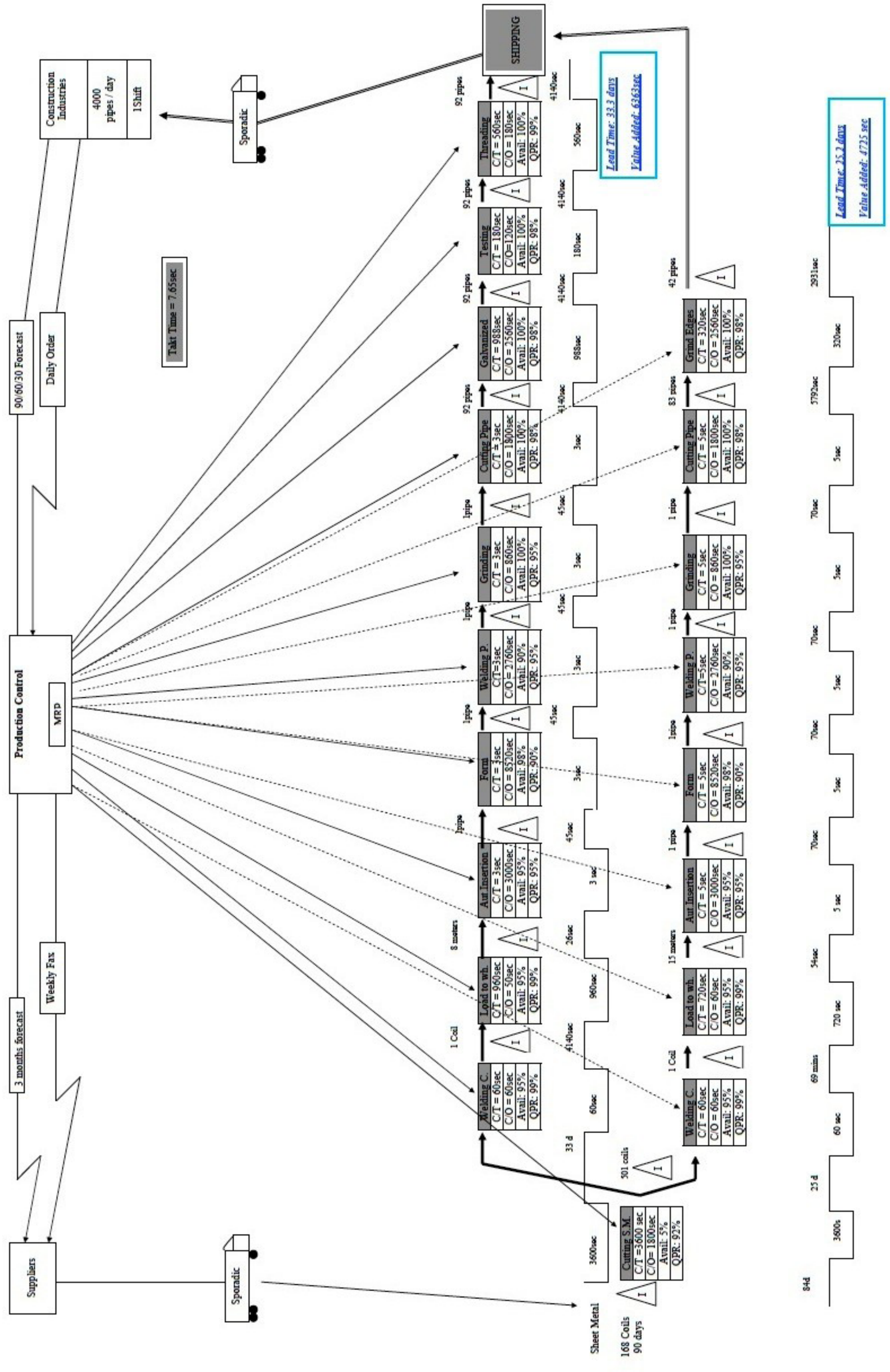
Manufacture according to the Takt Time: As it has already examined in the previous paragraphs, none of the processes is in balance with the Takt time. Therefore the need to produce every part or product according to the Takt value is highly recommended.

Pull System Supermarket: It is not very common used in the steel pipe making industry, but it may be useful for those areas where continuous flow is not possible and then the products have to be packed into batches. The main aim of pull system supermarket is to control the production at supplying processes without trying to schedule. Pull system supermarkets can only work by applying at the same time KanBan production control principles. Therefore, the customer can go to the supermarket and withdraw what it needs but he/she has to inform the Kanban system, so the supplier will receive the KanBan signal and replace the products taken by the customer.

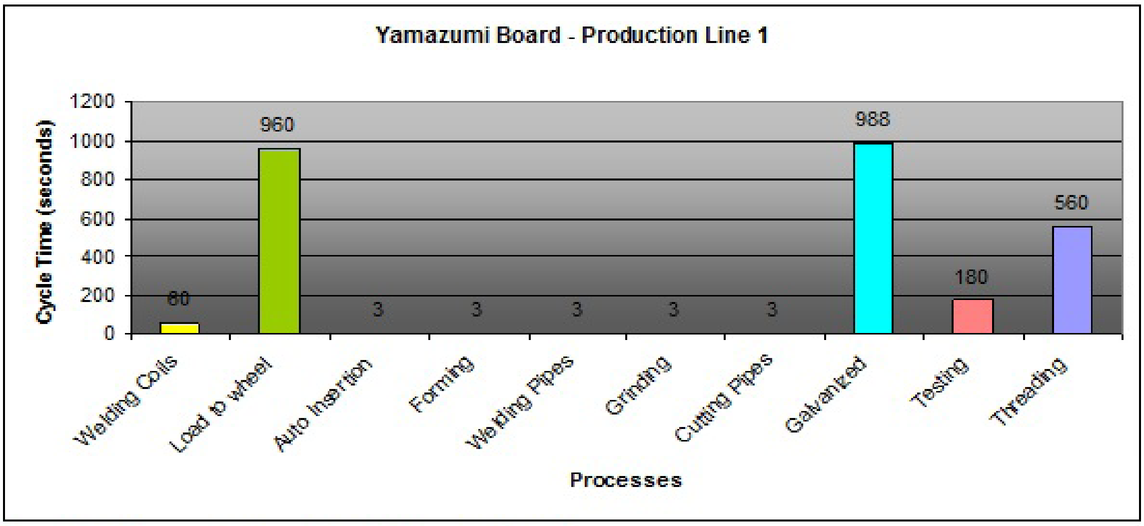
FIFO Lane: Fifo Lane or First In First Out. This methodology can installed between two processes with the aim of substituting from a supermarket but maintaining the flow constant between them. When FIFO lane is full, automatically sends a signal and the supplier stop to supply the first process.

Pacemaker process: “By using supermarket pull systems, you will typically need to schedule only one point in your door-to-

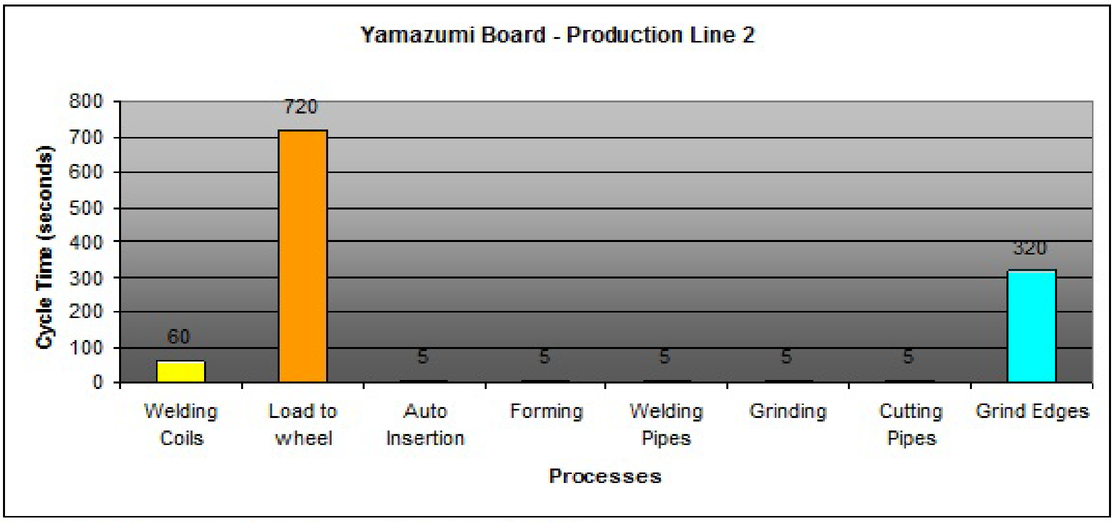
Appendix 2: Current State Map



Appendix 3: Yamazumi Boards



Graph 1. Yamazumi Board – Production Line 1



Graph 2. Yamazumi Board – Production Line 2

door value stream. This point is called the pacemaker process" or in other terms, pacemaker process is the right tool to stop the overproduction phenomenon at any process.

Please refer to Appendix 4 for Future State Map.

Implementation of Future State Map

The recommended changes and improvements ensure smooth flow of the production line, low inventories and producing within the Takt time.

These are:

Set up / Changeover reduction: If we refer back to the current state map, it is clearly visible that the changeover time of some resources is enormous. For instance the changeover time of auto insertion and forming processes take up to 7 hours. This is because the changeover tools need to be organized better and also train one more employee who can support the changeover process with the aim to reduce the time into half.

Process Improvement: The processes at the beginning and at the end of the production line are not in balance with the Takt time. The result of this is the phenomenon of high inventories. Therefore, these processes have to be improved by reducing their cycle time, but without affecting the quality of the products.

Organization: The storage areas have to be organized better by applying 5S Housekeeping methodology and KanBan production control. These improvements will reduce the time of finding the right coil or the right pipe by approximately 35%. For instance, the inventory after the cutting process of the sheet metal coils is 501 coils. So, the operator needs much time to find the right coil within of 501 coils.

Transportation: Unnecessary transportation can be reduced by setting up the last three processes (testing, threading and grinding) into a cell. Also, the company has only one trolley

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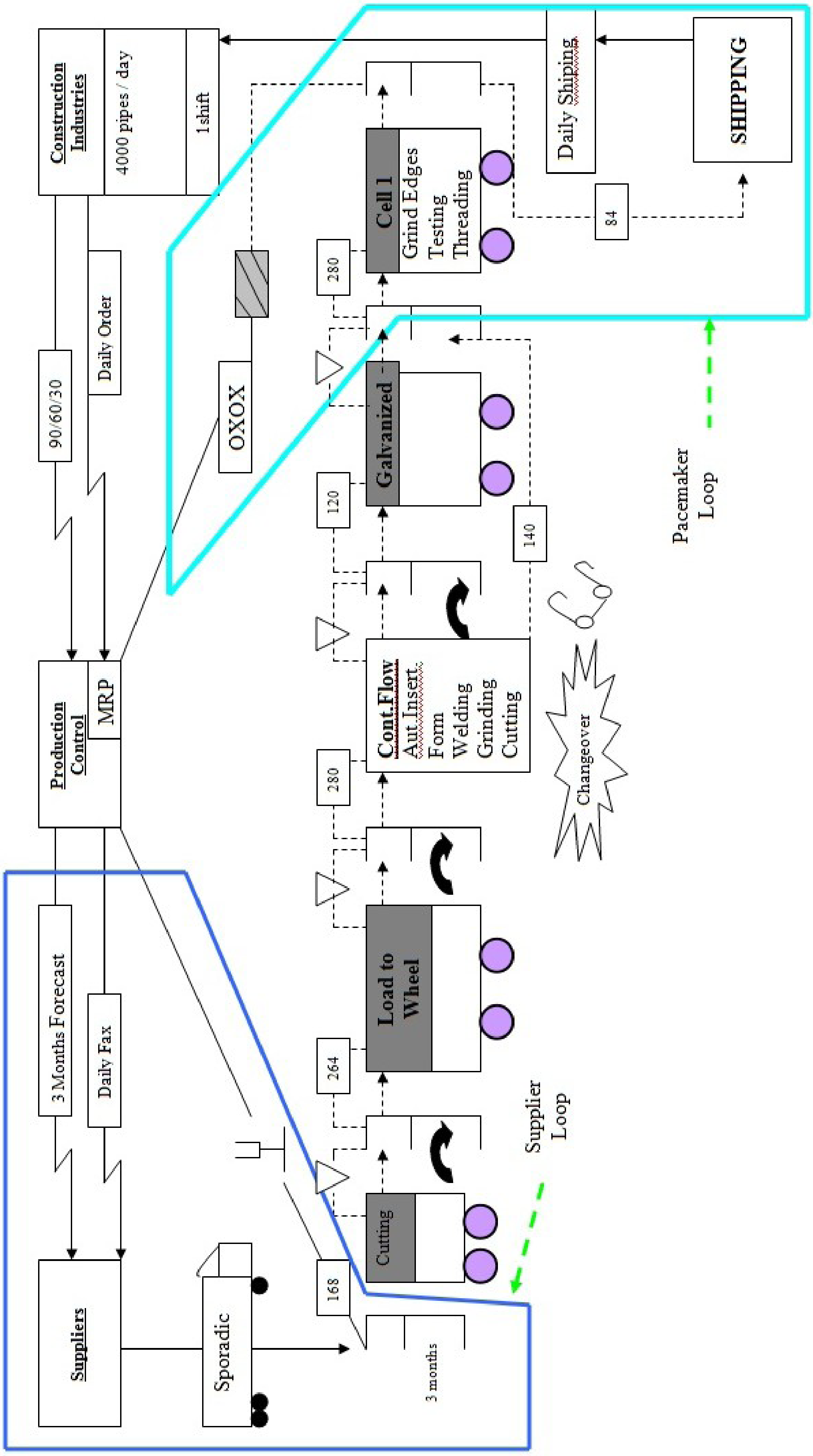
Appendix 4: Future State Map



for the internal transportation of the pipes. All the other transportations use bridge crane, which is dangerous, slow, and costs more. Therefore, the installation of new trolleys or in some cases conveyors is highly recommended.

Total Productive Maintenance: One of the problems occurred in the machines is the sudden shutdown due to problems with the Program Logic Controls (PLC). From a quick look on the manuals of the machines, this is because the sensors which are connected with the PLCs sometimes are not cleaned well. The result of this is that the sensors send incomplete signals to the PLCs and PLCs crashed. Therefore, TPM has to be scheduled in a daily or weekly basis to prevent sudden shutdowns of the machines [8-12].

The Benefits after applying Lean Principles

- Reduced scrap and waste
- Reduced Inventory levels
- Reduce lead time
- Improve customers satisfaction
- Deliver on time without any delays
- Preventing sudden shutdowns of the machines
- Transportation distances may be reduced
- Less human effort and time by organizing better the storage areas
- Processes can be balanced to produce according to Takt Time
- Changeover time can be reduced into half by train one more employee
- Pull system introduced to avoid high inventory levels
- Continuous flow is highly recommended for the steel industry
- Introducing cellular manufacturing in three processes with the aim of reducing cost and eliminates the unnecessary transportation
- The defective products can be inspected early.

Furthermore, the assessment team recommended to the owners of the company that with a capital of €17,000 (for buying new equipment) the total daily loss can be reduced from €32,000 to €7,000 [9].

Discussion and Conclusion

During the analysis of this research work were examined the most important and basic principles of lean manufacturing and how they can be implemented in a real production line. The purpose for that was to implement theory into practice. Initially, the report focused in the analysis of the lean manufacturing in terms of Lean's definition and the need for lean. The result from this chapter is that within an organization there are many different kinds of waste, but lean is coming as an antidote to all these kinds of waste. The second parts consists of lean manufacturing tools and techniques, where are described the most important and related lean tools and techniques with the production line. Hence, a company has the opportunity to choose the right lean tool for the right areas that needs to be improved and save a lot of money and time.

Also, another result from this report is how a company can become a lean enterprise with special focus on small and medium sized enterprises because they comprise the 90% of all enterprises around Europe.

Furthermore, in a company everything starts with an assessment. So, it was necessary to describe all the steps required for a complete assessment with the aim of gaining the best possible results. After the assessment, the next step is to implement the changes found through the analysis and assessment.

The final part of this report was a case study, which refers to a real company with special examination at the production line. The purpose of this examination was to define the benefits after applying the right lean tools and techniques in a production line.

The above case study is in the engineering sector of advanced research and may be applied in many technologies covering materials production, energy, environment or agriculture [13-22] and more cases in respect to engineering advanced productions.

Acknowledgements

This work has been supported by the European Commission under HORIZON2020, H2020-EU.2.1.5.1. - Technologies for Factories of the Future: Z-Fact0r Project ID: 723906 "Zero-defect manufacturing strategies towards on-line production management for European factories".

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