Lean management manufacturing methods for Stone Group International

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Abstract

This consulting project was written as part of the MSc in Management at the International Hellenic University.

Big Greek manufacturing companies face serious challenges about production. In this competitive environment, lean management manufacturing methods which have been applied in abroad successfully, can offer significant advantages for Greek production companies. Lean management is related to the optimization of processes and activities within production. In this project, the current production process of Stone Group International is examined with the proposed managerial methods.

Furthermore, Stone Group International provided the freedom of examinating the current production process within its factory in Kavalari, Thessaloniki. According to the scope of the project, the proposed management tools have been analyzed and implemented through six graphs and six tables graphs and represented as a single model in order to create a competitive advantage in the production sector. These methods have been identified after research through books and academic papers and sites. The main purpose of this research is to contribute to the efficiency of the company's production processes.

Keywords: Lean management methods, manufacturing tools

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Contents

List of Graphs

List of Tables

1. Introduction

1.1 Description of the report

The report examines a specific field in manufacturing world, lean management manufacturing philosophy, the benefits that companies and big organizations gain adapting it and its implementation in Stone Group International. The Greek company is a successful manufacturing organization aiming to integrate the key principles of lean management through a continuous effort of evolution and development.

The main objective of this report is to offer methods and tools to the production department of the company to increase its operations efficiency and the whole company generally to adapt the lean thinking ideology. The theoretical presentation of methods and tools are based on academic papers, books, journals and sites and are presented in the literature review of this report through a theoretical analysis. Moreover, it is presented how these methodologies can be applied in Stone Group International and the benefits of this implementation. Additionally, there are some constraints and limitations in the data that are important and might affect with a negative way the results of this project.

1.2 Outline of the report

The report is organized in eight chapters, one conclusion and references.

In chapter 2, the scope of the project is discussed and the company is presented with some important general information.
In chapter 3, the aims and main research objectives of this projected are presented and analyzed, making clear why this project is important for Stone Group International.
In chapter 4, the literature review is presented. The theoretical part of what is lean management manufacturing and the applied lean methods are described so as to be clear for the reader. This analysis is based on books, academic papers, journals and sites.
In chapter 5, the ways for acquiring data are conferred according to the production of the company.
In chapter 6, a detailed description of the four production units of the factory is presented which is the main issue of the research.
In chapter 7, the lean management manufacturing methods are implemented to the current production process. Graphical and table representations make the analysis more understandable.
In chapter 8, are discussed the outcomes of the analysis combined with the description of some important project constraints.
In chapter 9, a concise presentation of the conclusion is presented.

2. Background and scope of the project

In this chapter the company is presented briefly, its operations and the issue that is examined in the whole report.

2.1 Background of the firm

Stone Group International founded in 1981 and its headquarters are located in the city of Thessaloniki. Furthermore, it is one of the largest marble companies in Europe and a global white marble ambassador with exports to 85 countries. It has four factories nationwide, two in Drama, one in Veroia, one in Thessaloniki, six quarries and multiple distribution agreements with other quarries in Greece and abroad.

The main competitive advantage of the company is the quality of the marbles that provides in the industry worldwide after their processing period at the factories of the company as well as the variety of marbles that it has on its list of products. Most of the clients are foreign companies that undertake to make projects of great importance for the construction of building facilities.

The uniqueness of Greek marble on a global level in terms of quality and durability in combination with the Greek Economic crisis and the sharp fall of the sales in the Greek market during the previous decade, has led the Greek firms to penetrate mainly in other countries. Moreover, Greek Marble companies have increased their competitiveness growthing their market share in foreign markets, holding a dominant position in the international marble industry. It is characteristic that[1] during the period 2009-2017 the Greek marble exportation has increased by an average annual rate of 16.8% in quantity and 15.3% in value.

In 2017, Stone Group International ranked 4th in turnover rate in Greek companies in the sector. Its market share compared to other Greek companies in the total value of marble exports is around 7%. Also, Stone Group International ranked 5th in gross profit and 6th in profit before tax while during the years 2016-2018, the value of its sales were €32.894.687 in 2016, €31.428.681 in 2017 and €28.480.064 in 2018. Main competitors are Pavlidis S.A. Marble- Granite, F.H.L. Kiriakidis, Iktinos Hellas S.A., Birros Hellenic Marble S.A.

The last years, the company is trying to apply lean methods according to global standards. The factory has recently begun to work on a specific lean tool 5S so as to reduce the time required to carry out all the activities through the better organization and classification of materials used in its product lines. In addition to, nine of its executives have been trained in lean Six Sigma Yellow Belt techniques.

[1] Retrieved from https://*dir.icap.gr/acci/EBEAmeleti.pdf*.

2.2 Scope of the project

The rivalry amongst marble enterprises in the Greek industry is high as the demand for Greek marble, due to its quality and uniqueness, is growing from foreign countries. The project has undertaken to examine four production lines of the plant located in Thessaloniki, with the main aim of proposing lean management methods for the optimization of the production process that will give the production a differentiated operation strategy, compared to the competing companies in the Greek industry.

3. Aims and Research Objectives of this project

In this chapter the main Aims and research objectives are described within the frame of the dissertation project.

3.1 Aims

In the production business world, there are specific methodologies of applying lean management. A significant aim of the report is to examine and evaluate a specific number of lean management methods and tools that have achieved in the past to change the attitude, the mentality of big manufacturing companies, the history of the evolution of the production procedure during the last century and how these methods can be implemented on the current production procedure of Stone Group International.

Also, there is a growing demand of big firms and companies that choose to cooperate with major university institutions with the aim of professional evolution. Hellenic International University and Stone Group International can be involved with constant cooperation as two continuous learning organizations.

3.2 Research Objectives

First of all, main objective of the report is to examine the current situation of the four production lines. Gathering information and analyzing them contribute to a better understanding of how the production lines are operating, cooperating each other and the way they are linked so as to produce the final product.

After the examination, the research tries to identify possible activities that add value and optimize the production line though lean methods. The most important goal for the production department is to increase the productivity number of the marbles by adding elements that contribute to the production goals. Additionally, identifying losses and unnecessary tasks inside the production procedure can cut operational costs and save money for the company.

The most important research objective of this report is to recommend right practical solutions based on the lean methodologies that are under consideration and will lead to better operational results and achievement of the production targets that have been set by the production department of the company.

4. LITERATURE REVIEW

The methodology of operations and manufacturing management is vast. Therefore, here, an introduction is provided regarding lean management and its associated methods, ideas and tools that will be used in the analysis of the four production lines of Stone Group International.

4.1. Lean management in a general perspective

As Su Mi Dahlgaard-Park and Jostein Pettersen points out[2], a management system with a high recognition and popularity at a global level such as lean management should have a clear and precise definition. On the contrary, the definition of lean management is extremely indefinite, creating not only communication difficulties at a professional level but mainly creating problems of understanding the true meaning of what essentially is lean management. In addition, this sub chapter will not try to give a precise definition, yet to approach the lean management as a concept and ideology.

Toyota is the company which invented this particular management system. It is usually referred as Lean manufacturing, Lean production or Toyota Production System. However, Lean management is the preferred description of this concept external to Toyota Motor Corporation because it does not only cover the production department but also a wider range that can be applied to each organization sector.[3]

Developed between the period 1948-1975, by the Japanese industrial engineers Taiichi Ohno and Eiji Toyoda. After the end of World War II and the negative consequences that left behind in the whole country, Toyota did not have appropriate space, money and inventory to meet the customers' needs. Poor resources forced the company to create this managerial system, finding ways to optimize its production line and gradually creating a strong competitive advantage in the world industry through the production[4]. It is an evolutionary form of Ford's ideas and implementations in the automotive industry,[5] focusing on the flow of the process with low inventory volumes, levelled out production, just in time production and addition of activities into the

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[2] Dahlgaard-Park, Su Mi, and Jostein Pettersen. "Defining lean production: some conceptual and practical issues." *The TQM journal* (2009).

[3] Emiliani, Mario L. "Origins of lean management in America: the role of Connecticut businesses." *Journal of management History* 12.2 (2006): 167-184.

[4] Liker, Jeffrey K. *The Toyota way*. Esensi, 2005.

[5] Liker, Jeffrey K. *Becoming lean: Inside stories of US manufacturers*. CRC Press, 1997.

procedures which satisfy the customer needs and standardization of them accompanied with eliminating resources of wastes from the process.[6]

According to Jeffrey K.Liker, the man who examined and studied for almost two decades the Japanese production system within Toyota, Lean management or Toyota production system is the ideal managerial system for an organization to evolve, be recognized and contribute to the society in ethical ways. Many organizations tried in the past to cooperate with Toyota to adopt the lean management thinking. For instance, the reopening of the factory NUMMI (1984-2010) between General Motors with Toyota, which adopted the Japanese manufacturing model was an innovative way of managing in the US market. Moreover, Toyota suppliers who cooperate with the Japanese company adopted Lean management model with the purpose of joint development and evolution.[7] It is estimated that until 2017 Toyota has shared it's know how since its self-productive experience with more than 320 small to medium-sized manufacturers, governmental organizations and non-profit organizations dealing with disaster relief, hunger relief, health care and many other[8].

Pillars and Key principles of Lean Philosophy

Sanjay Bhasin and Peter Burcher state[9] that lean manufacturing should be viewed by each organization as a philosophy and embraced as an ideology[10], a particular way of thinking in order to succeed and not as a procedure or a set of tools that will yield profits.

According to Jeffrey K.Liker, the success of lean philosophy is based on two pillars, which are the continuous improvement and respect for the people. Continuous improvement is the constant evolution and development of an organization which depends on team effort as a ''lean learning enterprise'' and respect for the people is the mutual comprehension, appreciation and trust amongst the members of an organization. Without these two conditions, lean management cannot be applied effectively.

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[6]Liker, Jeffrey K. *The Toyota way*. Esensi, 2005.

[7] Liker, Jeffrey K. *The Toyota way*. Esensi, 2005.
[8] Retrieved from https*://www.tssc.com/about.php*.
[9] Bhasin, Sanjay, and Peter Burcher. "Lean viewed as a philosophy." *Journal of manufacturing technology management* 17.1 (2006): 56-72.

[10] Bhasin, Sanjay. "Performance of organisations treating lean as an ideology." *Business Process Management Journal* 17.6 (2011): 986-1011.

Besides these two main pillars, Jeffrey K. Liker also points out 14 key principles which govern the mentality of Lean philosophy and more particular, the ''Lean thinking''.

1. Base your management decisions on a long-term philosophy, even at the expense of short-term financial goals.
2. Create continuous process flow to bring problems to the surface.
3. Use pull systems to avoid overproduction.
4. Level out the workload (heijunka).
5. Build a culture of stopping to fix problems to get quality right the first time.
6. Standardized tasks are the foundation for continuous improvement and employee empowerment.
7. Use visual control so no problems are hidden.
8. Use only reliable, thoroughly tested technology that serves your people and processes.
9. Grow leaders who thoroughly understand the work, live the philosophy and teach it to others.
10. Develop exceptional people and teams who follow your company's philosophy.
11. Respect your extended network of partners and suppliers by challenging them and helping them improve.
12. Go and see for yourself to thoroughly understand the situation.
13. Make decisions slowly by consensus, thoroughly considering all options; implement decisions rapidly.
14. Become a learning organization through relentless reflection and continuous improvement [11] [12].

[11] Liker, Jeffrey K. *The Toyota way*. Esensi, 2005.

[12] Ljungblom, Mia. "Ethics and Lean Management–a paradox?." *International Journal of Quality and Service Sciences* 6.2/3 (2014): 191-202.

Relations between Zen-Buddhism, Kaizen philosophy, Lean management

Zen-Buddhism introduced in Japan during the period 1185-1333.It is one of the two major religions in Japanese culture (Zen Buddhism and Shinto) and one of the most important philosophy/religious movements in Japan history, along with Shintoism and Confucianism[13].Moreover, it has its roots in Chinese and Indian languages and it refers to the meditation process, based on a rigorous self-control with the purpose of continuous self-improvement through teaching to every human-being the importance of living in the present achieving internal enlightenment[14] [15].

Kaizen is a Japanese term and initially used by Maasaki Imai (1986) and can be translated as change *(kai)* and good *(zen),* meaning change for better[16]. In managerial terms, Kaizen is defined as the continuous improvement and development of all members within an organization, including managers, employees and workers alike. Kaizen is an integral part of the lean philosophy, covering issues of continuous improvement and total quality management within an organization. According to Daniel Carnerud research, Kaizen is occasionally presented as the missing link when organizations in the West do not derive the expected benefits of Japanese management philosophies[17]. As Andrea Chiarini, Claudio Baccarani and Vittorio Mascherpa state through their research[18], Kaizen is a way of thinking which encourages and empowers everyone to identify where and how even small changes can be made to benefit the business, their team or their individual performance. Additionally, the research states that Zen-Buddhism affected to a large extent Kaizen principles in Japan.

Andrea Chiarini, Claudio Baccarani and Vittorio Mascherpa indicate that Zen-Buddhism became an inspiration source for Lean thinking. Furthermore, there are significant

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[13] Retrieved from https*://web-japan.org/factsheet/en/pdf/e20_religion.pdf*.
[14] Retrieved from https*://www.quora.com/What-is-the-point-of-Zen*.
[15] Retrieved from https*://www.theguardian.com/commentisfree/belief/2012/sep/21/zen-buddhism-lessons*.

[16] Chiarini, Andrea, Claudio Baccarani, and Vittorio Mascherpa. "Lean production, Toyota Production System and Kaizen philosophy: A conceptual analysis from the perspective of Zen Buddhism." *The TQM Journal* 30.4 (2018): 425-438.

[17] Carnerud, Daniel, Carmen Jaca, and Ingela Bäckström. "Kaizen and continuous improvement–trends and patterns over 30 years." *The TQM Journal* 30.4 (2018): 371-390.

[18] Chiarini, Andrea, Claudio Baccarani, and Vittorio Mascherpa. "Lean production, Toyota Production System and Kaizen philosophy: A conceptual analysis from the perspective of Zen Buddhism." *The TQM Journal* 30.4 (2018): 425-438.

similarities in the way of thinking between Zen-Buddhism, Kaizen and Lean management, as a result of the Japanese culture.

According to the three authors[19], Zen Buddhism may seem more like a practical religion or movement instead of a theoretical and abstract philosophy. The only way to understand Zen is to practice and directly observe the phenomenon rather than the sequence of an explanation and reasoning. In a similar way, lean thinking includes an important key principle, the *Genchi Genbutsu* (go to source).Moreover, Genchi Genbutsu teaches that problems can be solved and the processes can be improved by going to the source, observe and understand the situation. Taiichi Ohno, the father of TPS, used to emphasize to the employees of Toyota the importance of observing a situation with concentration so as to validate their data or to get to the root of the problem[20].

Moreover, Zen-Buddhism teaches how to be in the present. How to get away from the past, which is no longer and how not to get involved in the future that is not yet, and just to be rooted, concentrate on what it is. In the same direction, a basic key principle of Lean thinking, Just-In-Time states that the production process of an enterprise should only produce the necessary products, in the necessary time, in the necessary quantity. When a production system is based on historical data and an uncertain future, the plant could produce large amounts of waste, such as large batch sizes and huge inventory. In this way, JIT can be seen not only as a way of organizing the production system but first of all as a way of thinking about time and action at the same time that the company receives a customer's order[21].

Also, Zen-Buddhism emphasizes the importance of respecting the people and their contributions to the social harmony through their actions. Additionally, Buddhism is trying to strengthen the sense of respect for all people, constant self-improvement, as well as discipline and perseverance in their daily life.

In the same way, as shown previously, one of the two basic pillars of Lean thinking is the respect for the people. Moreover, the Japanese production model promotes the need for continuous improvement of the individuals within the organization (Kaizen).

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[19] Chiarini, Andrea, Claudio Baccarani, and Vittorio Mascherpa. "Lean production, Toyota Production System and Kaizen philosophy: A conceptual analysis from the perspective of Zen Buddhism." *The TQM Journal* 30.4 (2018): 425-438.

[20] Liker, Jeffrey K. *The Toyota way*. Esensi, 2005.

[21] Chiarini, Andrea, Claudio Baccarani, and Vittorio Mascherpa. "Lean production, Toyota Production System and Kaizen philosophy: A conceptual analysis from the perspective of Zen Buddhism." *The TQM Journal* 30.4 (2018): 425-438.

Furthermore, based on the authors and their research[22], the Japanese way of lean thinking considers that respect for people is based on teamwork. Berger and Suárez-Barraza considered teamwork as a fundamental for creating a whatever Kaizen environment. Additionally, Buddhism of Zen has a specific practice called zazenkai or meditation in the group where students are encouraged to come together in quick meetings, sometimes without the master, to improve the art of meditation[23].

4.2. One piece flow

As Jeffrey K.Liker states[24], continuous flow is the heart of Lean message. One piece flow or continuous flow connects all the activities and tasks carried out from the employees of a production process, shortening and minimizing the time the raw materials enter the production process until the final product comes out of it. According to Teruyuki Minoura[25], former President of Toyota Motor Manufacturing in North America, it can be considered as a risky lean implementation since the emergence of a problem requires the whole line to stop production and the members of the team have to think for a solution immediately. However, through thinking team, members grow and became better team members and people.

Moreover, Schonberger emphasizes[26] the importance of reducing delivery times and decreasing inventories through the implementation of the basic principles of lean management. Additionally, through his research he points out that the correct and rational divisions of labor between the workers who compromise the production lines, contribute to the creation of an adequate and continuous production flow at factory level.

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[22] Chiarini, Andrea, Claudio Baccarani, and Vittorio Mascherpa. "Lean production, Toyota Production System and Kaizen philosophy: A conceptual analysis from the perspective of Zen Buddhism." *The TQM Journal* 30.4 (2018): 425-438.

[23] Chiarini, Andrea, Claudio Baccarani, and Vittorio Mascherpa. "Lean production, Toyota Production System and Kaizen philosophy: A conceptual analysis from the perspective of Zen Buddhism." *The TQM Journal* 30.4 (2018): 425-438.

[24] Liker, Jeffrey K. *The Toyota way*. Esensi, 2005.

[25] Liker, Jeffrey K. *The Toyota way*. Esensi, 2005.

[26] Arturo Garza-Reyes, Jose, et al. "The development of a lean park homes production process using process flow and simulation methods." *Journal of Manufacturing Technology Management 23.2 (2012): 178-197.*

A lean expression[27] is that by creating a flow so as to reduce the number and level of inventories, exposes immediately the problems that exist within the production line. The authors liken the production process with a boat in a sea. If the water (which represents the inventories) is at high levels, the rocks cannot be seen by the boat, slowing the progress and creating turbulence. If the water level is reduced, the rocks are immediately seen by the ship exposing the problems to the sea surface.

The goal of creating One piece flow is to remove any waste effort that is not adding value in the production procedure. Jeffrey K.Liker points out eight non-value adding wastes (muda in Japanese) that should be eliminated from the procedure:

1. Overproduction

2. Waiting

3. Unnecessary transport

4. Over processing

5. Excess inventory

6. Unnecessary movement

7. Defects

8. Unused employee creativity

Benefits

The successful implementation of One-Piece flow aims minimize and eliminate the seven categories as outlined above. Jeffrey K.Liker presents[28] seven important benefits through a felicitous continuous flow production:

1. Builds in Quality. The unified flow offers quality in the production process. The diagnosis of defects is detected in a fast way by the employees of the continuous production procedure. If defects are identified, the production flow automatically stops to resolve it so that it will not appear again in the future.

2. Creates Real Flexibility. A significant orientation of the continuous line is to reduce the lead times within the production. Moreover, decreasing lead times amongst the

[27] Slack, Nigel, Chambers, Stuart, Johnson, Robert, Betts, Alan. *Operations and Process Management: Principles and Practise for Strategic Impact.* Prentice Hall, 2008
[28] Liker, Jeffrey K. *The Toyota way*. Esensi, 2005.

production lines, the members of the team obtain the necessary flexibility to devote time and energy to issues that optimize the production in other specific sectors.

3. Creates Higher Productivity. Two of the most important differences of the One-Piece flow against Ford's mass production, is the reduction of inventories between production lines and defective products. Furthermore, with low inventories and defect-products, it is easier for a company to measure the value added activities of the employees related to just-in-time production, figuring out how many employees are needed to achieve a certain production rate which can lead to increased productivity. In a specific case of Toyota's non-profit corporation TSSC (Toyota Supplier Support Center)[29] which undertakes projects of various companies to optimize their production line, when they changed a mass-producing supplier to a TPS-style line, they achieved at least a 100% improvement in labor productivity.

4. Frees up Floor Space. There is no need to create new or additional facilities, as the reduction of inventories or equipment that is not considered necessary offers free space.

5. Improves Safety. Continuous flow aims to reduce the distances between the activities, which also leads to the transfer of smaller batches within the factory. As a result, the risk of an accident is greatly reduced.

6. Improves morale. With the use of One piece flow, employees feel that they are more involved in their tasks, giving them a greater sense of satisfaction as they offer much more value added work. Wiremold, implementing lean Management[30], achieved a gradual increase in improving the morale of its employees. Prior to implementing lean management, only 60% of its employees considered the company to be a good place to work. Every year this percentage increased, surpassing 70% in the fourth year.

7. Reduces Cost of Inventory. The non-production of inventories reduces the costs of the business, freeing up cash for important company transactions. Also, the inventory obsolescence of a company goes down.

[29] Liker, Jeffrey K. *The Toyota way*. Esensi, 2005.
[30] Liker, Jeffrey K. *The Toyota way*. Esensi, 2005.

4.3 Takt Time

As Jeffrey K.Liker states[31], Takt-Time is the heart of one piece flow. Takt in German is the rhythm. Moreover, it is the rate of customer demand- the rate at which a customer purchases a product, programming the production process to meet the exact time requirements of all the purchases without delay and unnecessary inventory, achieving just-in-time production.

Kenley states that[32], Takt time, in terms of construction projects, is the overall rate of progress by which all construction activities should ideally move. At a productive and manufacturing level, if the enterprise produces at a faster rate than Takt-Time, then it will create an excess inventory that is considered as waste. On the other hand, if the production produces at a slower rate than Takt-Time, activities will take longer than their optimum finishing time. Furthermore, it will delay the succeeding tasks of Takt-Time, causing an inadequate production rate, which cannot satisfy the customer's needs.

Takt-Time can be applied in repetitive manufacturing operations, as One Piece flow. The formula[33] that is used to define Takt-Time is,

Takt-Time=Total Available Production Time/Average Customer Demand.

Total Available Production Time refers to the time at which production is active by producing product quantities while Average Customer Demand is the total number of orders for the product of an enterprise and the demand whose production is intended to cover at a certain rhythm.

[31] Liker, Jeffrey K. *The Toyota way*. Esensi, 2005.
[32]Yassine, Tarek, et al. "Implementing takt-time planning in construction to improve work flow." *Proc. 22nd Ann. Conf. of the Int'l Group for Lean Construction*. 2014.
[33] Retrieved from https*://kanbanize.com/continuous-flow/takt-time/*.

4.4 Levelling out the production (Heijunka)

The concept of leveling production is not new and has been studied and practiced by the industrial community for over 60 years[34].

Heijunka is the Japanese word for leveling out the production by both volume and production mix[35]. Moreover, it takes the total volume of orders in a period and levels them so the same amount and mix are being made each day, keeping small production batches and building what the customer (internal or external) wants.

According to Hoda El Maraghy and Ahmed M.Deif[36], Production levelling aims to accomplish a smooth and stable production process without over-production or underproduction. Moreover, it intends to achieve a capacity balance and synchronization of all production activities and operations over time in a way that responds accurately and flexibly to customer demand for system's products. However, such normalization can be costly challenging its successful implementation.

Phillip Marksberry , Badurdeen Fazleena and M. A. Maginnis [37] also emphasize the importance but also the necessity to achieve a levelled out production by volume with a particular production mix. They underline that Production levelling has been used to optimally sequence various product models during manufacturing so that the fluctuation in customers demand is smoothed across the planning period, enabling cost reductions and improved efficiencies.

Elimination of Muda, Muri, Mura

As mentioned in sub chapter 4.2, the disposal of Muda and its 8 wastes(overproduction, waiting, unnecessary transport, over processing, excess inventory, unnecessary movement, defects, unused employ activity) is a key objective in order to create a continuous flow, and therefore a leveling out production. However, focusing only to the 8 wastes may cause serious dysfunctions within the production process.

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[34] Marksberry, Phillip, Fazleena Badurdeen, and M. A. Maginnis. "An investigation of Toyota's social-technical systems in production levelling." *Journal of manufacturing technology management* 22.5 (2011): 604-620.

[35] Liker, Jeffrey K. *The Toyota way*. Esensi, 2005.

[36] ElMaraghy, Hoda, and Ahmed M. Deif. "Dynamic modelling of impact of lean policies on production levelling feasibility." *CIRP Annals* 63.1 (2014): 389-392

[37] Marksberry, Phillip, Fazleena Badurdeen, and M. A. Maginnis. "An investigation of Toyota's social-technical systems in production levelling." *Journal of manufacturing technology management* 22.5 (2011): 604-620.

Jeffrey K.Liker[38] refers to the elimination of Muda, Muri and Mura. The three M's are:

Muda-*Non-value-added*. The most familiar M which includes the eight wastes. The eight wastes consists of activities that lengthen the lead times, cause extra movements and motion so as to get part or tools necessary for the operation tasks, create excess inventory or result in any type of wasting.

Muri- *Overburdening people or equipment*. According to some perceptions, Muri is the opposite of Muda. Muri is pushing a machine or a person beyond natural limits. Overburdening people results negatively in quality and safety problems, while overburdening equipment causes breakdowns and defects.

Mura- *Unevenness*. Mura results from a no normal production schedule or fluctuating production volumes owing to internal problems, like downtimes or missing parts or defects. Moreover, it can be viewed as a resolution of the other two, Muda and Muri.

As the author[39] underlines, in order to apply Heijunka with a successful way, it is fundamental to eliminate Mura, which is fundamental of eliminating Muda and Muri. For a manufacturing enterprise, the easiest part is the identification of any of the eight wastes and excludes it from the process. However, the difficult part is to stabilize the production system creating evenness- a true balanced lean flow of work.

Benefits

Jeffrey K.Liker also states in his book[40], using a specific example, four basic benefits a production unit could gain through levelled production. These benefits are:

1. *Flexibility to make what the customer wants when they want it*. Decrease the inventory and the problems that create within a plant.

2. *Reduced risk of unsold goods.* A plant producing only the necessary and exact quantity of product in accordance with orders eliminates the acquisition and maintenance of inventory.

3. *Balanced use of labor and machines.* A plant can create a schedule based on standardized work and level out production without overloading or under loading production machines in combination with the employees tasks.This will lead to a balanced and manageable workload every day.

[38] Liker, Jeffrey K. *The Toyota way*. Esensi, 2005.
[39] Liker, Jeffrey K. *The Toyota way*. Esensi, 2005.
[40] Liker, Jeffrey K. *The Toyota way*. Esensi, 2005.

4. *Smoothed demand on upstream processes and the plant's suppliers.* If the plant uses a just-in-time system for production processes and for received raw materials from suppliers, it will allow suppliers to level out their activities, cut unnecessary costs and pass some savings on to the customers so that each of the cooperating companies gets the benefits of levelling.

4.5 Kanban

Kanban, which is a Japanese word[41], is broadly known as a signal. According to Jeffrey K.Liker and his statement[42], Kanban is a pull production system focused on managing and ensuring the correct flow of materials between the various activities within the production unit successfully, achieving just-in-time transfer. In particular, Kanban aims to trigger the production between the diverse stages of an operation. It can be translated as sign, signboard, doorplate, poster, billboard or card.

David Claudio and Ananth Krishnamurthy state that the last few years, Kanban has become quite popular and is used by several productive units around the world. His success is mainly due to the fact that his use is quite simple and very efficient. This system achieves in a successful way to explicitly limit the inventories by using Kanban cards. In particular, when a unit is consumed from the inventory, a Kanban signal is sent upstream to begin work to replace this inventory.

In the same way, Nigel Slack, Stuart Chambers, Robert Johnston and Alan Betts point out[43] that Kanban in its simplest form can be used with cards and with other forms, for just-in-time material-transfer. Due to the importance of the system, the authors state that the Kanban is sometimes referred to as the invisible conveyor the transfer of items between the stages of an operation. Moreover, it serves three significant purposes:

- It is an instruction for the proceeding process to send more.
- It is a visual control, aiming to show up areas of overproduction or lack of synchronization.
- It is a tool for continuous improvement (Kaizen). Toyotas statement is that through continuous improvement, the number of Kanban should be reduced over time.

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[41] Rahman, Nor Azian Abdul, Sariwati Mohd Sharif, and Mashitah Mohamed Esa. "Lean manufacturing case study with Kanban system implementation." *Procedia Economics and Finance* 7 (2013): 174-180.
[42] Liker, Jeffrey K. *The Toyota way*. Esensi, 2005.
[43] Slack, Nigel, Chambers, Stuart, Johnson, Robert, Betts, Alan. *Operations and Process Management: Principles and Practise for Strategic Impact.* Prentice Hall, 2008

Benefits

According to Nor Azian Abdul Rahman, Sariwati Mohd Sharif and Mashitah Mohamed Esa [44] and their research, nowadays in order to achieve the excellence of construction, most organizations have developed various techniques and methods to make their production processes productive and efficient. Most Japanese companies apply the Kanban system because they save costs by eliminating production, developing flexible workstations, reducing waste and scrap, minimizing waiting times and logistics costs. Thus, reducing inventory levels and overheads costs.

Moreover, Jeffrey K Liker emphasizes[45] the reduction of inventory as a major benefit and Ohno's statement that the inventory is just waste. As he states, for a factory using Kanban system means to avoid overproduction. Also, he underlines the simplicity using the Kanban system, forcing the employees and the whole production system to a continuous improvement procedure.

4.6 Andon

Andon [46] in Lean manufacturing is a system designed to alert operators and managers in real time that a problem has occurred during the production line and an immediate corrective action can be taken. [47]It comes from the Jidoka methodology used in Toyota's production system, which has empowered operators and employees to recognize defects or actions out of task requirements and take the initiative to stop the line so as to fix the problem.

Andon can take many forms. It can be activated by an operator pulling a cable or pushing a button - or it can be switched on automatically by the equipment when a problem is detected. Whether it's a lack of components, equipment malfunctions, or security concerns, Andon in Lean manufacturing's job is to stop work so the team gathers and executes a root cause analysis in real time - and quickly implement a solution. Once the problem is resolved and the work continues, the incident is recorded as part of a continuous improvement system.

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[44] Rahman, Nor Azian Abdul, Sariwati Mohd Sharif, and Mashitah Mohamed Esa. "Lean manufacturing case study with Kanban system implementation." *Procedia Economics and Finance* 7 (2013): 174-180.
[45] Liker, Jeffrey K. *The Toyota way*. Esensi, 2005.
[46] Liker, Jeffrey K. *The Toyota way*. Esensi, 2005.
[47] Retrieved from https:*//leankit.com/learn/lean/what-is-andon-in-lean-manufacturing/*.

According to Jeffrey K.Liker, once the Andon system is activated the team leader has 15-30 seconds to fix the problem. Team Leaders are carefully trained in standardized procedures and how they should respond when an Andon call occurs during the production. If the problem has not been resolved, the production line stops in order for all members to take collective action. Jeffrey K Liker points out that the greatest advantage of Andon system stopping the production is the reason that all workers are all afraid of.

Also, he insists that with the implementation of the system, the group acquires a mindset to solve all the issues by bringing to the surface everything that may delay or create a problem in the production of a plant. Therefore, the system will eliminate any waste that is not useful and value added for the production procedure. Moreover, Sérgio L. Kemmer, Martina A. Saraiva, Luiz F. M. Heineck, Ana Valéria. L. Pacheco , Marcos de V. Novaes , Carlos A. M. A. Mourão , Luiz C. R. Moreira[48] though their research support that Andon system provides the opportunity to all the managers, supervisors and the employees to continually learn through this mindset system, improving the continuous flow and avoiding the rework.

4.7 Value Stream Mapping

According Singh, Harwinder and Amandeep Singh [49], Value Flow Mapping (VSM) works as a business improvement tool in Lean Management so as to help visualize the entire production process, representing both material flow and information. The aim of this lean method is to identify all types of waste in the flow of value and take the necessary measures to eliminate them. VSM helps develop a "current state map" that shows a visual representation of how the company operates. Moreover, it records the process information and flow of information that can be used to identify the underlying waste, problems and opportunities. Once the current status map is analyzed, the future state map can then be produced to show how the company could work more effectively.

[48] Kemmer, Sérgio L., et al. "The use of andon in high rise building." *proceedings of the 14th annual conference of the international group for lean construction*. Santiago: IGLC, 2006.

[49] Singh, Harwinder, and Amandeep Singh. "Application of lean manufacturing using value stream mapping in an auto-parts manufacturing unit." *Journal of Advances in Management Research* 10.1 (2013): 72-84

In the same direction, Naga Vamsi Krishna Jasti through his research[50] underlines the significance of Value Stream Mapping, as an important Lean Management method. He points out that value flow matching (VSM) allows the identification of value added activities. In other words, VSM is constantly pursuing the objective of reducing waste to increase value. Therefore, by applying the VSM which could help to identify operating losses, organizations will be able to eliminate operational losses and move towards creating more value for the customer.

Development and Implementation of Value Stream Mapping

Jeffrey K. Liker in his book states[51] that the development and implementation of an effectiveness value stream Map can be achieved through a Kaizen Workshop. As he underlines, Kaizen Workshop is typically a one-week event where the participants-members of the team (usually no more than 15 people) analyse the current process, develop a lean vision for the process and begin the implementation. Kaizen Workshop is divided in three phases: preparation, the actual workshop, sustaining and continuous improvement after a workshop.

Phase One: Preparation for the Workshop

There are five important things for the pre-workshop so as to facilitate the flow and the effective use of participants' time:

Clearly define the scope: Specify the start point or triggering where the process actually begins and what the final deliverable products for the customers are.

Set objectives: The process owner must set measurable goals to reach the team. Moreover, the objectives should be aggressive to ensure that participants are challenged to come up with innovative process changes compared to the current situation.

Create preliminary current state map: A sub-group is walking through all the production procedure and the production lines so as to document the steps of the process, the time it takes to perform the task(task times), and wait times between the processes. In case there is no data for some processes, there will be time to collect it prior to the workshop.

Collect all relevant documents: Also the sub-group should collect samples of forms and documents for each step while the preliminary current state map is being created.

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[50] Dadashnejad, Ali-Asghar, and Changiz Valmohammadi. "Investigating the effect of value stream mapping on operational losses: a case study." *Journal of Engineering, Design and Technology* 16.3 (2018): 478-500.

[51] Liker, Jeffrey K. *The Toyota way*. Esensi, 2005.

Moreover, the copies of all standard procedures which the process affects should also be available for the workshop.

Post a preliminary current state map in the team room: Each of the tasks in the process are listed on their own sheet (8.5''x11'' preferred) of paper and posted on butcher-block paper on the wall. Furthermore, space is left among task boxes to allow for notes and modifications during the workshop.

Phase Two: The Kaizen Workshop

According to Jeffrey K.Liker, Phase two is divided in five steps:

Step 1.Who is the customer? : In the first step, the team tries to identify the true customers' needs. In addition to, the various tasks of the production procedure are examined whether they add value or not on these needs.

Step 2.Analyze current state: In the second step, the members of the team walk through the production process, observe the various tasks and activities that take place in the production, discuss with the employees about the procedure, so as surface problems or to search out new ideas for improvement. Once the team is finished, validates all the data, modify the processing steps as required and discriminate all the activities which are value added, non-value added and non-value added but required.

After document the current state, the final part of this step is the calculation of the summary metrics of the business process. Jeffrey K.Liker underlines some common but significant measures:

- Lead time: total time the product stays in the system
- Value-added ratio: sum of the value-added time divided by lead time
- Travel distance of the product
- Travel distance of people doing the work
- Productivity: people hours per transaction
- Number of handoffs
- Quality rate: percent of products that go through the process the first time with no defects

Then, the team reviews the objectives set in the preliminary stage to see if they are plausible and whether they have to add new objectives.

Step 3.Develop future state vision: In this step, the team is ready to develop a lean future state. One important way to achieve this is to use group brainstorming. The team gathers all the ideas, written with sticky notes, evaluates them and promotes the best ideas in order to achieve the targeted objectives, within the group

context. As Jeffrey K.Liker states, the most significant concepts that should be part of the future state vision include the following:

- Creating one-piece flow.
- Arranging work centers to align with value streams, so as to support customers in a one-piece flow.
- Using cross-functional teams when needed to avoid handoffs.
- Identifying a value stream of a case manager who is responsible for the service from start to finish from the customer's perspective.
- Levelling (load level) the number of transactions, where possible, to balance the workload.
- Building quality in the process instead of inspecting it (e.g., eliminate unnecessary approvals, checking, review cycles).
- Standardization of the tasks and work-document standardized work-sheets.
- Eliminate redundant systems, such as reconciliation across different people.
- Including visual displays and controls.

After the completion of the future state map, the team compares the new process metrics with the current state metrics to quantify the expected savings and to proceed to the next step, which is the implementation.

Step 4.*Implementation:* The future state map is divided into segments and the participants break into subgroups to work in each segment so as to make the future state vision a reality. Jeffrey K.Liker underlines significant implementation activities during the workshop:

- Redistribution workplaces to facilitate one-piece flow
- Workplace organization(5S and visual displays)
- Creation of standardized working instructions
- Revision of corporate procedures
- Redesigning forms and documents
- Problem-solving activities to uncover root causes of quality problems
- Specifications or even some changes for any information technology required to support the improved process
- Training people in the new process

Step 5.Evaluate: This step includes the performance measurement of the previous steps. The team archives the current state metrics and compares them with the future state metrics in order to ascertain the improvement of the specific targets- objectives. Moreover, at this stage the discussion of existing metrics is also important and the elimination of those that are unnecessary and are opposed to the implementation of lean future state vision.

Phase three: After the workshop-Sustaining and Continuous Improvement

After the first two phases, the team meets on a weekly basis so as to do the following:

- Review the status of the open action items from the project plan.
- Review process metrics to ensure improvements are being achieved.
- Discuss additional opportunities for improvements.
- Continue to improve the process

Also, senior management should do monthly reviews of the lean status board to evaluate metrics, open items on the project plan and resolve any roadblocks to implementation.

5. Data source Methodology

In this chapter, are presented the specific ways in which information was collected during the project so as to describe and analyze the four production lines related to the marble processing.
Moreover, this collection of information has been indispensable for an adequate understanding of marble processing and the operation of the four product lines in order to propose suitable lean management manufacturing methods for improvement.

Informal Interviews: KPIs data and the way Stone Group International use it, financial information and statements of the company were provided by the Director of the Stone Group International.
Information about the statistical performance of the four production units as well as the productivity and the working hours of the four production lines were provided by the production manager of the plant.
A detailed analysis of the operations of the four production lines, Machine 1, Machine 2, Machine 3, Machine 4 and the distribution of the daily performance of the workers were extracted by team-leaders of the four production lines. Also, one worker of each production line contributed to the extraction of information related to duties and responsibilities within every production unit.

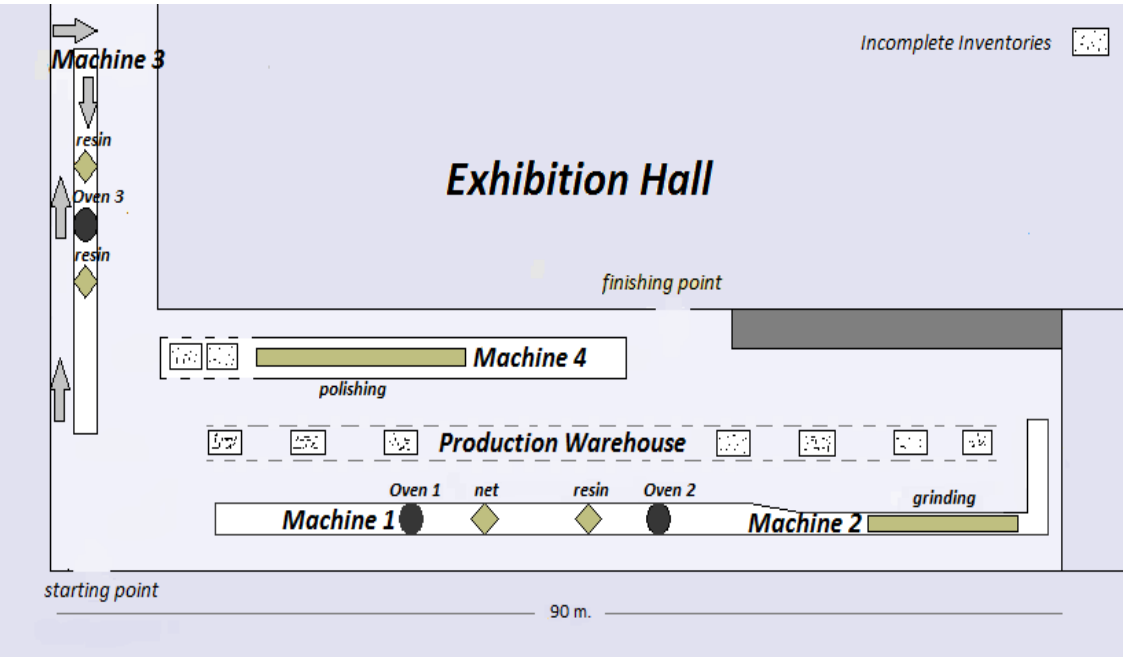
Own observation: Own observations during March to May were held into the production line to clarify the operations involved in the flow of marble production and the performance of workers during the performance of their duties.
Also, time measurements were held to measure the current efficiency of the production process as well as spatial measurements within the production area in order to propose the lean manufacturing methods without structural problems.

6. Description of the four production lines

The description of the production process includes a brief outline of the four production lines as well as the role and the main tasks of each production line including the KPIs that the factory uses to evaluate its production performance.

6.1 Description

The production lines are Machine 1, Machine 2, Machine 3 and Machine 4. All the marbles pass through the four production lines and two cranes undertake to transfer all the processing marbles within the production area till to their final storage in the exhibition area. First of all, before the starting point of the four examined production lines, large volumes of marbles arrive from the cooperating or owned quarries at the factory, which will be stored in an external storage space. Prior to entering the four production lines, big marble cutting machines with the help of recycled water cut all these large volumes so as to give them a square shape and cut them into plates in specific dimensions of centimeters to meet the needs of customers.



Graph 1: the current production flow within the four production lines.

Machine 1

The working hours for Machine 1 are 16 hours a day with two workers on the line and one team-leader worker on every shift. The production line produces on average 375 pieces of marble in a daily basis. Machine 1 undertakes to provide quality to the marble which has been reduced by its time consuming transport from the quarries to the factory but also by cutting it from a large volume into plates. The marble plate enters the first oven, dries from the moisture of the water for about 2.5 hours, exits the oven and covered with neck and resin. If there is no need to place a net on the

surface of the marble then resin is only placed. The plate enters the second oven for about 3.5 hours to dry the resin on the marble. In addition to, the marble returns underground to the area where its surface is covered with resin, in cases where it will need to be resurfaced for a second time.

Machine 2

Machine 2 is the consequence of Machine 1 and undertakes to grind the surface of the marble by using diamonds and stones of specific sizes. The working hours of Machine 2 are 16 hours and produces on average 375 pieces of marble a day. Furthermore, one worker is placed in every shift who is being monitored by the team-leader of Machine 1. Once the grinding of marble is finished, the marble will be stored in the area of Production Warehouse or will be transferred to Machine 3 or Machine 4.

Machine 3

The working hours for Machine 3 are 8 hours a day with 3 workers and one team leader worker on the shift. The production line operates eight hours and produces on average 100 pieces of marble a day. In Machine 3 are carried out almost the same activities and tasks as in Machine 1. When the marble enters the production unit, it crosses underground the Machine in order to get to the oven for preheating. Once the marble has been preheated, one layer of resin is placed on its surface and a second one when it is necessary. After the first layer of marble, the product will enter the oven for about 30 minutes to dry, while for the second layering the marble will stay in the oven for almost two hours. Also as Machine 1, Machine 2 can provide the option of placing net on the marble surface at the beginning of the production line where the first layer of resin is placed. It should be noted that this oven consists of 57 positions for marble pre-heating.

Machine 4

Machine 4 is operating 16 hours every day and produces 300 pieces of marble with one worker and one team-leader on every shift. The production line Machine 4 undertakes to clean and polish the marble. Each marble plate is polished with diamonds and stones of different sizes in order to clean it from the recyclable water and give it a smooth and sleek surface. Finally, the marble plate is placed together with the remaining plates of the same order, and is transferred to the exhibition area so as to be visible to the customers.

It should be noted that the Machine 4 accepts the marbles for processing as long as the polymerization of resin is totally completed after the resin processing. Specifically, once the marble comes out of the procedure of Machine 1 and 3, the polymerization of resin is completed by 92%.In order to be completed by 100%, the marble remains in the production environment unprocessing for a 24 hours.

Production warehouse

It is the place where temporary unfinished marbles are stored during their processing. The production warehouse includes incomplete inventories that come for temporary storage from Machines 2, 3 and 4. In some cases, the warehouse includes complete inventories that are placed temporarily until their final storage to the Exhibition Hall.

6.2 Production process evaluation

The factory measures the monthly performance of its production lines with an Overall Equipment Effectiveness report. Therefore, this report produces some important KPI's which reflect the efficiency and effectiveness of the production procedure performing its statistical performance.

Initially, the presentation of the K.P.I.s used by the factory requires the explanation of the following variables which form the basis of their measurement.

- Calendar Time = is the maximum potential duration of annual production of the factory. Moreover, it includes 365 days of 24 hours for a year.
- Loading Time= is calculated from calendar time by subtracting the agreed shutdowns that are related to the general operating conditions of the factory (weekend production, legal holidays, annual closure) and to the method of operating the installations(overtime).
- Gross Operating Time= is calculated from loading time by subtracting the voluntary shutdowns due to absence of commercial load or full silos.
- Net Operating Time= is calculated from gross operating time by subtracting induced shutdowns (No material, no power, no water, no person/ pallet/ space), voluntary shutdowns (preventive maintance, quality-engineering-testing, Break, Cleaning, start/ stop/ change) and random shutdowns (mechanical or electrical breakdowns, Ember PM) while the production process is operating.
- Valuable Operating Time= is calculated from Net Operating Time by subtracting the non-quality and sub-performance.

KPIs

Based on the above variables that affect the production process of the plant, this research lists the Key Performance Indicators used by the production for its evaluation process and then four tables showing from January to June the average performance of KPIs for each production line combined with their targets.

- Load Rate= Gross Operational Time**/** Calendar Time

Loading rate represents the percentage of time that an operation is scheduled to operate compared to the total Calendar Time that is available.

- Availability Rate= Gross Operational Time**/** Loading Time

Availability rate represents the percentage of scheduled time that the operation is available to operate.

- Performance Rate= Net Operating Time**/** Gross Operating Time

Performance rate characterizes the reliability of the installations, reveals all interruptions and shutdowns of production for various reasons.

- Quality Rate= Valuable Operating Time**/** Net Operating Time

Quality rate characterises the malfunctions or variations of speed that mean that the expected quantity of product is not produced.

- O.E.E.= Valuable Operating Time**/** Loading Time

Overall Equipment efficiency rate reflects the efficiency of the production.

- C.E.E.= Valuable Operating Time**/** Calendar Time

Calendar equipment efficiency measures the theoretical use of the investment, integrating the overall planning approach.

MACHINE 1	Actual	Target
Load Rate	36.4%	> 90%
Availab. Rate	100%	> 90%
Perform. Rate	91%	> 95%
Quality Rate	114.8%	> 99%
OEE	104.5%	> 85%
CEE	38%	> 85%

Table 1- six month OEE performance

MACHINE 2	Actual	Target
Load Rate	42.3%	> 90%
Availab. Rate	100%	> 90%
Perform. Rate	78.5%	> 95%
Quality Rate	101.9%	> 99%
OEE	80%	> 85%
CEE	34%	> 85%

Table 2- six month OEE performance

MACHINE 3	Actual	Target
Load Rate	46.4%	> 90%
Availab.Rate	100%	> 90%
Perform.Rate	88%	> 95%
Quality Rate	108.7%	> 99%
OEE	95.65%	> 85%
CEE	44.4%	> 85%

Table 3- six month OEE performance

MACHINE 4	Actual	Target
Load Rate	47.2%	> 90%
Availab.Rate	100%	> 90%
Perform. Rate	83.9%	> 95%
Quality Rate	92.8%	> 99%
OEE	77.9%	> 85%
CEE	37%	> 85%

Table 4- six month OEE performance

The four tables present the four production lines of the factory within the six Key Performance Indicators that the company uses and its effectiveness compared to the targets set by the company over a period of six months.

In load rate, the average rate of the four production lines indicates is low in contrast with the target due to non-operating days, holidays and weekends which decrease the specific KPI performance.

In Availability rate, the operating process in the four production units is operating 100% in contrast with the available scheduled time without any losses.

In performance rate, the effectiveness of this specific KPI indicates that there are losses within the four production lines owing to voluntary, induced and random shutdowns which do not allow the four Machines to achieve the target.

In Quality rate, the KPI is performing effectively due the over performance of the workers in relation with the target. Hence, there are prospects for better results for all the production lines. Only Machine 4 is not overpassing the target.

In OEE, the KPI is measuring the operating effectiveness of the four production lines within the production process. Only Machine 1 and 2 overpass the target.

In CEE, the KPI is indicating the overall effectiveness of the production operation related with the overall calendar time. Therefore, as in load rate, the non-operating days, holidays and weekends affect the performance with a negative way.

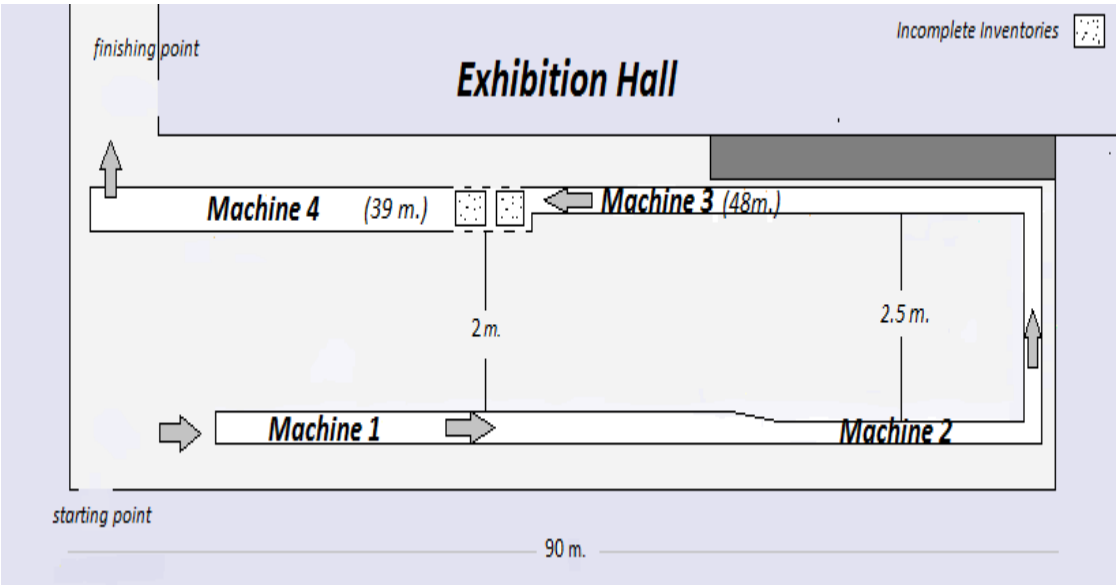
It should be noted that the changes proposed on the next chapter Analysis which are based on the lean methods affect only the three KPIs (Performance rate, Quality rate, OEE) which are related to the operating time of the factory compromising prospects for better operational results.

7. Analysis

In this section, the methodologies described theoretically in the previous chapter, are analyzed on the basis of the current spatial planning situation within the company's factory. Furthermore, the current section presents specific proposals-ideas drawn from the philosophy of lean management and the analysis of the above methodologies, with the use of graphical and table representation for each lean-method.

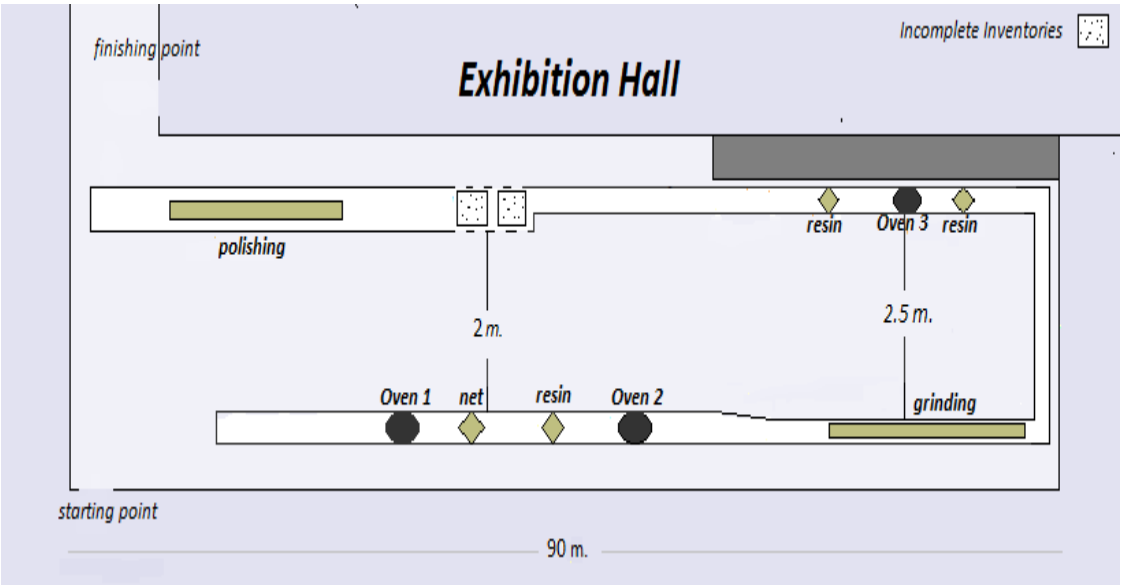
7.1 One piece flow

As the methodology described in the previous chapter, the plant adopts the idea and the philosophy of the one-piece flow, acquiring a production process with an integrated production line. According to the graph below, Machine 3 and Machine 4 have changed their positions within the production area in contrast with the current production area.



Graph 2: flow of the production with the applied method One piece flow

The graph 2 shows the production flow with the changed positions of the two production lines. Moreover, they perform their activities as a single flow, with no spatial problems within the production area. The third graph presents in a detailed and more completed way the new production process.



Graph 3: detailed production flow with the applied method One piece flow

The marble starts its process in Machine 1 where the marble is dried in the first oven, net and resin is putted on its surface and then it enters the second oven for drying and preheating. Then, the marble continues its process in Machine 2 for grinding. Moreover, Machine 3 undertakes to put resin to the opposite surface of the marble. Finally, the process is completed with polishing in the production line of the Machine 4 once the polymerization of resin is totally completed. It should be noted that the activities within every production unit do not change in relation with the current production process.

Also, it is characteristic that the big change lies in the fact that product lines 3 and 4 have changed their position differentiating the current production flow and the removal of the production warehouse freeing up space and reducing the incomplete inventories.

Benefits

The research outlines the benefits using One-piece flow within the production process.

- *The production process of the company by applying this methodology reduces the transport time required for a marble batch of seven pieces between its production lines*. Specifically:
  - In Graph 1, crane transports are approximately 4 minutes for a batch. In addition, the time for filling a batch from Machine 2 and Machine 3 for transporting them and the time of disconnection of the batch in order to enter Machine 3 and Machine 4 in separate pieces is about 20 minutes, without measuring the time of temporary storage of marble batches in the area of Production Warehouse. Therefore, there is a total time of about 27 minutes for a batch of seven marbles that includes the filling and transportation time.

Correspondingly, in Graph 3 the transport time for a batch of seven marbles within the production lines is approximately 3.5 minutes. According to the survey carried out, half-minute is required for the transport of a marble from Machine 2 to Machine 3 to the new production process.

- *Increased productivity*. The reduction of time within productive activities increases the collective productivity.
- *Removing one of the two cranes of the production process*. There is no need for the one crane which transports the batches of marble within the four Machines and the Production Warehouse. Therefore, there are no maintenance costs for the crane and the company can benefit financially by putting it up for sale. As a result, the flexibility of the procedure is increasing.
- *Reduction of Inventories*. One of the basic principles of One-piece flow is the reduction of Inventories inside the production increasing the company's liquidity with faster delivery of marbles to the company's customers. Moreover, marbles won't become obsolete.
- *Free production space*. As shown in Graph 2, there is more free space inside the production owing to reduction of Incomplete Inventories and the removal of the production warehouse.
- *Increased safety*. Removing the crane from the production process drastically reduces the risk of accidents.

KPI: There will be a raise in Quality Rate and in OEE into the four Machines as well the productivity of marbles will be increased.

Implementation

According to the research, the cost for applying One piece flow and changing the position of Machine 3 and Machine 4 within the production area is estimated at about €150,000€. In case the company attempts to sell the removal crane, its value is estimated at €15,000, placing also the two workers of the crane into Kaizen Workshop projects.

The research also proposes that the production process restructuring should take place in August where the monthly demand is low and the plant closes for a week due to summer holidays, adding a few more weeks depending on the work time-schedule.

One piece flow total costs estimation: €135.000(personal estimation).

7.2 Levelling out and Takt-Time

As it was analyzed in the previous section, basic principles of Heijunka are the smooth, stable and levelled-out flow of production with precise programming in activities within the production lines. Employees and workers should adopt a one piece/team philosophy that governs all activities within the factory constituting their consistent execution with accurate flow.

The research shows below an indicative table of how the idea Heijunka in combination with Takt-Time can be used in the company for a two-hour production process program with six different marble types.

	8.00	8.30	9.00	9.15	9.45	10.00
Monday	14 pieces marble i	14 pieces marble ii	14 pieces marble iii	7 pieces marble iv	14 pieces marble v	7 pieces marble vi
Tuesday	10 pieces marble ii	10 pieces marble iii	10 pieces marble v	5 pieces marble i	10 pieces marble vi	5 pieces marble iv
Wednesday	14 pieces marble iii	14 pieces marble i	14 pieces marble ii	7 pieces marble iv	14 pieces marble v	7 pieces marble vi
Thursday	12 pieces marble iv	12 pieces marble iii	12 pieces marble i	6 pieces marble v	12 pieces marble vi	6 pieces marble ii
Friday	10 pieces marble v	10 pieces marble iv	10 pieces marble ii	5 pieces marble i	10 pieces marble vi	5 pieces marble iii

Table 5: Sample of two hour weekly production program.

The six types of marbles are referred as marble I, marble ii, marble iii, marble vi, marble v marble iv and they are used by the company for the marble procedure. Next to each type of marble is the number of pieces for their daily production. In addition to, using the Takt-Time and the type that described in the previous chapter, the production of the company is in a position to monitor the demand of the customers through their orders, defining the production process of the different types of marbles, their daily production number and the precise time they will enter the procedure. In contrast with the current situation where the factory is producing no more than two types each day, production will have to include all types of marbles in small quantities on a daily basis in order to be able to meet the daily customer demand without creating a large number of reserves in specific types of marbles, achieving just in time production.

Benefits

The implementation of Heijunka combined with Takt-Time can generate significant benefits for all the operations that take place within the factory. These Benefits are:

- *Just in Time achievement*. Heijunka plays a decisive role in Just in Time achievement. Just in time can be achieved with activities related to the production process and the four production units, order delivery of marbles to the customers and received marbles from the quarries and equipment of suppliers that it is used inside the production procedure. Benefits of Just in time achievement are:
  - reducing the waste time within the operations
  -rising the production rate
  -Increasing the ability of synchronization of the tasks

- *Quarries start working with Heijunka Ideology.* The company owns six proprietary quarries. Once they start working on the same standard with the Stone Group International so as to achieve Just in Time through the transfer of large volumes of marble, they will cut unnecessary costs, passing savings to the company.
- *Small number of marble batches.* The creation of small marbles on the basis of the number of orders won't allow the increased inventories within the factory.
- *Balanced use of labor and machines*. The balance and stability within the enterprise's production process will contribute to the elimination of the Muri, by avoiding quality and safety problems for the people, and breakdowns and defects for the machines.

Implementation

As with the most proposed methods, adopting and achieving the methodologies requires a good understanding of them. Heijunka requires not extra personnel but a training program that teaches workers on a daily basis through specific supervision the assimilation of that particular way of thinking by a Lean coach.

Heijunka total costs estimation: -

7.3 Kanban

Kanban philosophy contributes to the levelled out philosophy of Heijunka and the single flow of One piece production. Therefore, Kanban cooperate in the efforts for ordering the precise supplies which are necessary for the marble production, the outstanding achievement of synchronization of all the activities within the production and the successful communication of the workers for the elimination of all the waste time that exists within the factory of the company.

7.3.1 Kanban board

On the basis of the Kanban methodology, the research suggests a smart and simple Kanban model using a Kanban board for the procurement of equipment and raw materials so as to reduce free space and increase the financial liquidity of the company within the production process as a solution for the bulk orders which increase the inventories of raw materials. Therefore, the report suggests that it should be applied first to Machine 4 for its inventories which uses 15 different types of stones and diamonds for the marble polishing. Table 3 shows the Kanban board for Machine 4.

Abrasive 1				
Abrasive 2				
Abrasive 3				
Abrasive 4				
Abrasive 5				
Abrasive 6				
Abrasive 7				
Abrasive 8				
Abrasive 9				
Abrasive 10				
Abrasive 11				
Abrasive 12				
Abrasive 13				
Abrasive 14				
Abrasive 15				
	Driver			

Table 6: Kanban board

In column 1 there are 15 different types of stone and marble. The remaining four columns represent for each kind of stone four boxes with a specific number of pieces.

It is noted that in blue color are the boxes that have finished during the procedure. Once a box has finished, the line employee reports it on the announcement material board with the blue color. The driver who is responsible for the orders of the rocks and the diamonds, for a certain period of time, which is programmed based on the use of stones, collects the number of missing boxes in order to start the order delivery from the supplier.

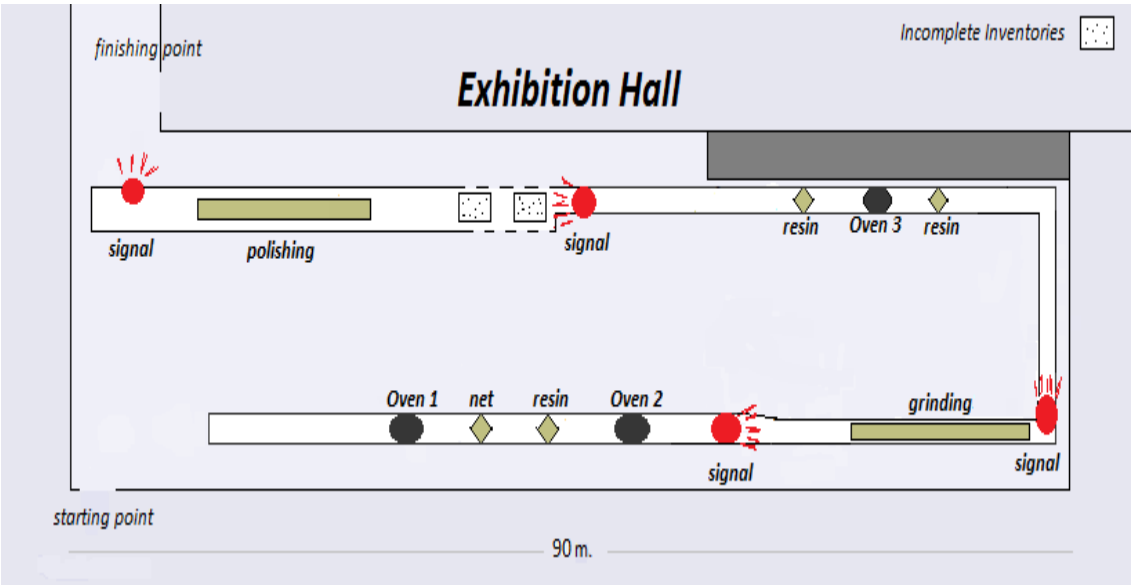
Once the Kanban philosophy is adopted precisely in Machine 4, the factory can also deal with all the supplies of the factory, collecting orders for all the production units as a single order.

Benefits

- *Just in Time achievement.* Just in Time achievement in materials procurement will contribute to the accurate planning of orders.
- *Low volume of materials inventory.* The small number of stones and diamonds will lead to more effective liquidity of Stone Group. Additionally, to free up the space within the production.
- *Just in time achievement with supplier.*The adoption of a similar model from the supplier through a specific training program can pass savings in Stone Group International in the future, through a professional relationship of mutual respect and cooperation.

7.3.2 Kanban signal

As an extension of One piece flow and Heijunka, the research also suggests a second model based on the Kanban signal in the four productive lines of the production. In the current situation, Graph 1 shows that the factory does not use a technical signal between the lines. Therefore, the use of Kanban will support more direct and efficient communication between the production units, reducing the response time of the workers. The graph 4 below, describes this model.



Graph 4: One piece flow with the applied method Kanban

The report proposes the installation of the Kanban at the end of each of the four production lines, where a special sound or visual equipment is settled, so as to give the signal to activate the next task. The red circular dots at the end of each production line represent the specific Kanban equipment. Moreover, this method will enable the workers to perform their duties with the fastest way.

Benefits

- *Reduce the response time of the employees.* The contiguous model constitutes a successful tried and tested application of the Toyota company. Kanban system will contribute to the reduction of response time of employees by increasing the speed of the production process, achieving Just in Time.
- *Contributes to a Levelled out production.* Just in Time achievement can be combined with a smooth, leveled out flow of production process.
- *Stops Inventories.* The most important reason why a Kanban system is operating within a production process. The Kanban equipment won't allow the production of Stone Group International to create inventories.

  KPI: There will be an increase in *Quality* rate and OEE in the four Machines while the Kanban signal will contribute significantly to the productivity growth.

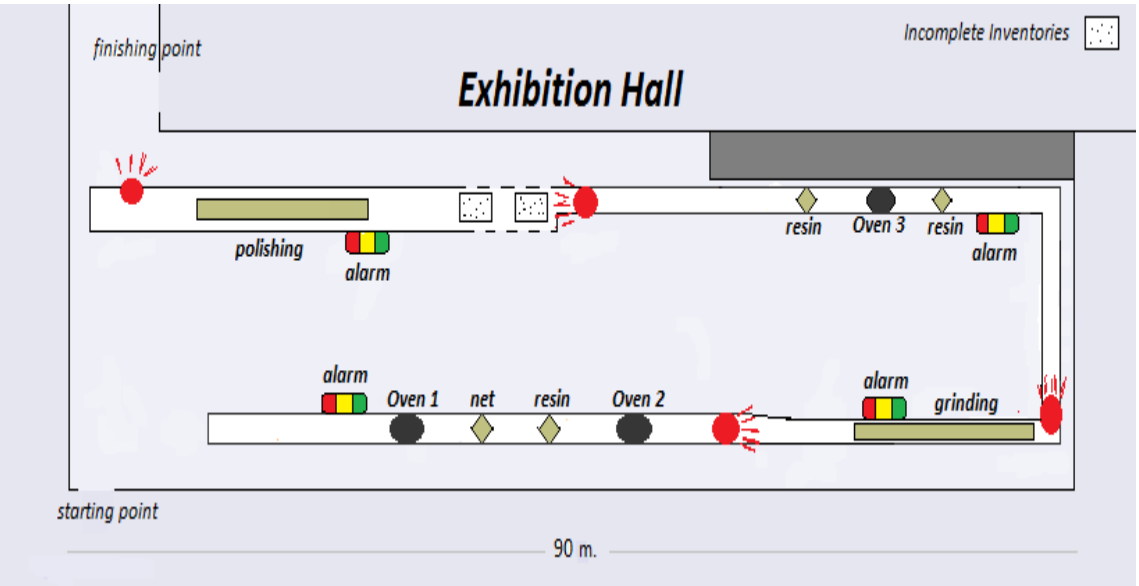
Implementation

Kanban system requires a specific program to assimilate that philosophy on a daily basis, as well as the purchase of a Kanban board and an audio or visual control system, such as signal lights enhanced with an audio support system. A Senior Lean coach will undertake to adapt the system's philosophy to all the factory workers.

Kanban total costs estimation = €1.000(personal estimation).

7.4 Andon

As a continuance of One piece flow, Heijunka and Kanban, Andon's philosophy contributes to the resolution of obvious or non-obvious problems. Therefore, Andon's method as an alert signal encourages employees to stop the processing line in case they see something unusual beyond the patterns and standards of the activities and tasks.



Graph 5: One piece flow with the applied method Andon

Based on the current situation (Graph 1) the factory does not use an alert model, a fact that sometimes does not allow the direct problem-solving without delay. Therefore Graph 5 represents the proposal of the research according to the methodology Andon. Every employee of the four production units should stop the line so that the whole team can contribute and solve the problem, without hiding it. Each line should contain an Andon system in specific areas where employees can directly alert the whole One-piece flow with alarm.

Once the employees observe an unusual task or activity, they press the yellow button. The team leader has a specific time (30 seconds) to solve the problem while the line is processing the marble. If it cannot solve the problem quickly, the line stops (red

button) to resolve the problem and not show up again in the future. It is a matter of culture and responsibility.

Benefits

- *Quality improvement though resolving errors.* May involve a small task that affects the quality of the product or a problem related to the mechanical equipment. Finding the solution the problem leads to its reference to the production line patterns so that it will not be resumed in the future.
- *Continuous learning mindset system*. The philosophy of Andon elaborates a specific way of team thinking about solving every problem or finding ways to continuously optimizing the processes in order for the production to become more efficient.

  KPI: There will be a raise in Performance rate owing to a decreased number of random shutdowns.

Implementation

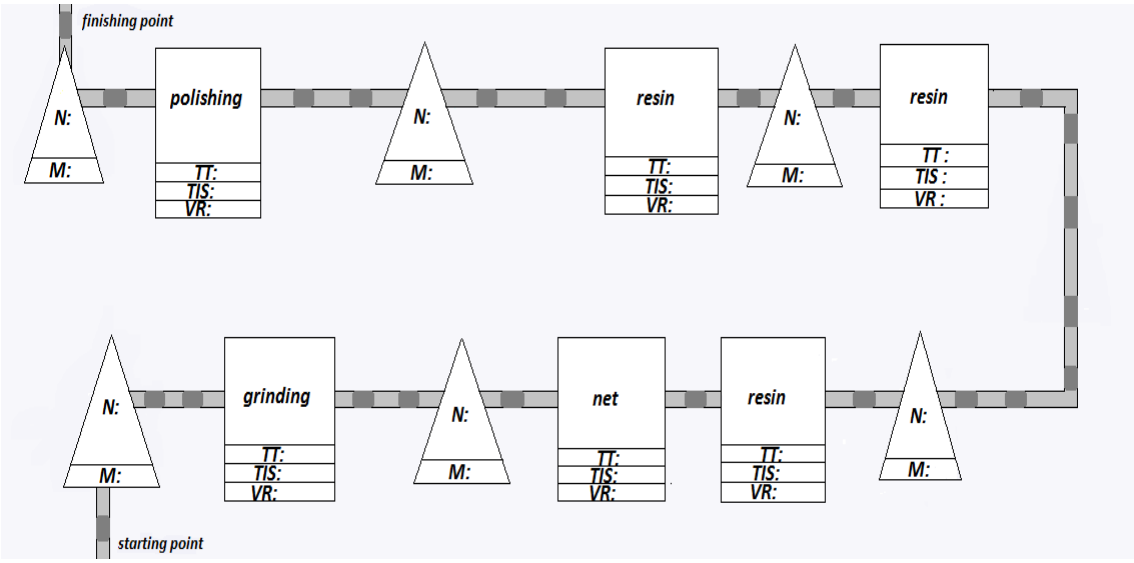
This method requires the purchase and the installment of an Andon system within the production lines in accordance with the graph 5.In addition to, the supervisors of each production line will have the control and the supervision of this system. Moreover, a Lean coach will contribute to the effective understanding and use of the system by workers.

Andon total costs estimation: €5.000-€10.000 (personal estimation).

7.5 Value Stream Map with Kaizen Workshop

Value Stream Map consists of the latest research proposal. In relation with the other methods, Value Stream Map has different characteristics and purpose. The scope of the Value Stream Mapping is to analyze to the maximum extent all the activities carried out within the production for its faster and higher quality performances.

Based on the current situation, the factory does not use a Kaizen workshop project. Graph 6 describes how this methodology will be applied to the company's plant through Kaizen workshop.



Graph 6: Value Stream Map of production

The boxes represent the processes while the triangles the inventories of marble that are waiting to enter the production process, to be processed and exit the production process towards to the Exhibition. Regarding to the triangles, letter N indicates the number of inventories while the letter M is the number of waiting minutes. Furthermore, processing boxes contain some basic key indicators like Task Time (TT), Time in System (TIS) and the value ratio (VR) which is the value added time of TT and TIS. The Value Stream Map of the production will contribute into the detailed processing of all data within the marble processing area.

Benefits

- *Detailed analysis of the processing activities of production.* This analysis will re-examine the various tasks of all the production lines that are carried out so as to effect positive changes in the quality and speed of processing, reducing unnecessary costs. As Akkoyun, Ozgur and Huseyin Ankara note[52], any serious effort to improve quality must take into account the costs associated with achieving it, since the objective of continuous improvement programs is not only to meet customer requirements but also to do so at the lowest cost.
- *Detailed analysis of incomplete Inventories.* The objective is to analyze the incomplete Inventories within the production process in order to reduce them and making a One piece flow with reduced waiting time, faster accompanied with a leveled production.
- *A continuous learning mentality.* Kaizen will start to provide elements of continuous learning among the managers and the employees of the factory, with the aim of optimizing the production.

KPI: There will be an increase in Performance rate, Quality rate and OEE as well the detailed examination of all the processes will contribute to an increased productivity, reduced shutdowns with a better team performance.

Implementation

This method requires the creation of a Kaizen team, five members in total. The experienced Lean coach leader will undertake to lead project and more than 1 member from each production unit will complete this group. Also, the company will have to hire an experienced Lean coach in Japanese lean philosophy and a Greek assistant lean coach in order to educate and train the personnel upon the philosophy of all these lean methods-proposals, contributing also to the long-term stability of One piece flow, Kanban, Andon, Value Stream Mapping. The salary of the lean coach will be about €60.000-€70.000 per year and for the assistant lean coach about €30.000-€35.000 per year.

VAM total costs estimation: €100.000 per year(personal estimation).

[52] Akkoyun, Ozgur, and Huseyin Ankara. "Cost of quality management: an empirical study from Turkish marble industry." *Scientific Research and Essays* 4.11 (2009): 1275-1285.

8. Discussion and Project constraints

In this section the overall assessment of the project as well as the recommendations proposed to achieve the initial objectives are discussed. However, there are some constraints and limitations that may hinder the smooth implementation of the above proposals.

This research suggests solutions to optimize the production of the company through the Analysis section. In addition to, it presents the benefits of the implementation, which are based on the description of methodologies section, such as reduced waste time, improvement of the product and the production activities within the process, increased productivity, ensurement of workers safety and adoption of a continuous learning mentality.

The most important proposal is the reorganization of the production area and its conversion according to the key principles of One piece flow. Furthermore, the continuous flow contributes directly for a levelled out production, achieved by the presence of audio or visual signals in every production unit, alerts for temporary shutdowns and their resolution and analysis of all the actions and activities of the production procedure, aiming at reviewing and optimizing the One piece flow.

The cooperation of the four production lines and their funciety as a single line through teamwork and trust amongst workers, is a key criterion for increasing the three KPIs, Quality rate, Performance rate and the OEE. The harmonious implementation of these proposals in the early months of its operation requires an adjustment period throughout a continuous training program. However, the aim of the production will be to double its productivity in all production units in the first half. After the first six months and the early adaption to the new production process, the plant will be able to set more realistic goals and KPI targets by gradually increasing its productivity, its efficiency in the various activities and tasks and the reduction of shutdowns through a continual improvement process.

Furthermore, the factory can also increase Load rate and CEE and their effectiveness if the factory decides to operate 1-2 weekends a month, contributing to the faster adaptation of workers to the new production line, increasing also the operational KPIs. However, the research does not suggest it due to the huge risk of overburdening the workers.

In addition, through these revolutionary changes, the factory will be challenged to keep the Availability rate at 100% in total.

On the other extreme, there are some constraints that affect with a negative way the results of the research. One of the main limitations is that the business world of production in Greece is not familiar with lean management manufacturing. In terms of

thinking and know-how in mass production, Greece is a country that has difficulties in responding to innovative ideas which are based on radical changes. Moreover, there is a great gap of expertise contrast to top countries such as Japan, America, and Germany. None of Greek companies have succeeded in the past to apply Lean manufacturing methods according to the Japanese model. According to Konstantinos Salonitis, Christos Tsinopoulos and their survey[53], there has not been any study focusing on lean implementation in Greek manufacturing sector. Additionally, Greek manufacturing companies cannot apply successfully lean management methods due to the absence of lean knowledge on lean philosophy, the resistance to change by the employees and financial barriers that can be associated with the financial crisis of the last decade.

An important constraint was the limited time of employees in contributing their knowledge to the completion of the project. The execution of their tasks on a daily basis was a constraint for questions, discussion and generally collecting information for the research related to the production of marble and the proposed solutions.

Furthermore, costly sacrifices are required for the implementation of this model. Changing the position of the production lines and stopping the production of marbles for a certain period of time is an important barrier to the implementation of this model.

Another significant constraint associated with the production process and the proposed solutions is that the polymerization of resin within the marble creates incomplete inventories during the production. This is an important constraint for the proposed One piece flow model, as the surface of the marble which has been planned for polishing is converted into an incomplete inventory after the completion of its processing in Machine 3. The fact is not in line with the One piece flow philosophy as well as its main objective is the removal of inventories within and outside the production. However, this constraint may be an issue for a future research on how to accelerate the polymerization process without reducing the quality.

[53] Salonitis, Konstantinos, and Christos Tsinopoulos. "Drivers and barriers of lean implementation in the Greek manufacturing sector." *Procedia CIRP* 57 (2016): 189-194.

9. Conclusions

In the current business world of marble production, the company has to face major challenges. Competition, high cost and demanding customers are causing pressure in a daily basis. Moreover, the emphasis on details is very important for this type of organizations. Specifically, production department performance makes the difference many times and the way operations are managed contributes to a significant competitive advantage. The research provided some important tools that have been applied in the past with success by huge companies such as Toyota, in order to manage with a more efficient way its production operations and activities within the production process, facing these challenges.

In a general context, the application of the proposed model requires a homogeneity of the proposed solutions. One piece flow is the basis of this model. Furthermore, it accelerates the production, remove waste time, inventories and most important it transmits the philosophy of unity without distinct production lines, but as a single one. In conjunction with the important tools of a levelled out production and Heijunka, Kanban, Andon, production increases the quality and gains economic benefits. Additionally, Visual stream Mapping contributes to the continuous development of these tools through Kaizen.

On the other hand, there are risks and constraints such as the economic sacrifices for the implementation of these solutions, the lack of knowledge and experience of lean manufacturing on the Greek market are obstacles that influence with a negative way the company's development.

The implementation of these lean management tools is a subversive approach for the Greek way of production thinking. However, it is recommended to Stone International Group to apply the proposed model so as to enhance its competitive advantage through Lean Management manufacturing.

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