Lean Manufacturing – Case Study on Production Line 2

Adriano Colaço da Silva

adrianosilva@ist.utl.pt

Instituto Superior Técnico, Universidade de Lisboa, Portugal

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Abstract

Social patterns have undergone enormous changes with advances in technology. Therefore, companies are striving for greater productive efficiency to meet the growing consumption demands and at the same time to keep flexible to the various market pressures by fulfilling continually new requirements. In this perspective, "Lean Thinking" arises aiming to eliminate unnecessary activities, preserving and increasing those with a greater added value. Consequently, "Lean Manufacturing" appears as a set of tools and methodologies that intend, through correct analysis and diagnosis of possible sources of waste, fostering in its continuous search process the application of techniques that when matured and applied, will allow its reduction or even elimination, maximizing client value.

In this work, some tools and methodologies were used for the analysis of the production Line 2 of the company Innovate Wet Wipes in Germany. In particular, the indicator OEE - Overall Equipment Effectiveness used to quantify the efficiency of the production processes and identify possible sources with major need of intervention. Next, the time study and work method analysis in addition with the use of the performance indicator KPI - Key Performance Indicator to calculate the OR - Occupancy Rate measured on critical stages of the process and finally, the use of the tool VSM - Value Stream Map to visualise the current company state.

Once the possible waste sources are identified, solutions were suggested steered by the tool SMED - Single Minute Exchange of Die to improve all the changeover process. Additionally, the 5S method to promote organization, cleanliness and safety in the workplace, resulting in a better and efficient performance of the tasks; the Kanban method for stock management; and poka-yoke with the aim of creating mechanisms to avoid human and procedural errors. In the end a future VSM for the company is suggested.

The proposed solutions in this work prospect structural, procedural, and behavioural changes in the current state of the company, aiming directly or indirectly a higher efficiency in activities and processes, as well as the reduction of costs and its associated times.

Keywords: Lean Manufacturing, OEE, SMED, Kanban, Poka-Yoke, VSM, 5S

1. Introduction

The world is still growing where competitiveness between companies increases by the rise of the average life expectancy, demographic growth and social behaviours. Companies search to satisfy the wishes and needs of their consumers through lower prices and high quality. In this context, Lean philosophy appears as a strategy that leads to a reduction of costs, lead time and waste, with direct effects on the productivity of a company. This is how Lean manufacturing contributes with a set of tools and methodologies capable to respond to those needs.

The present work has the purpose to analyse and characterize the current state of the production Line 2 of a wet wipes company. Thus, define strategies and use tools to find solutions for possible problems and its root causes, aiming continuous improvements as well as foreseeing its impacts.

Initially by historic-data-records, then time study and work method analysis, it was possible to obtain necessary information and data about the production Line 2 as well as to identify wastes inherent in the process. Moreover, the indicator OEE to measure its manufacturing efficiency. By creating a VSM, it was also possible to visualize and identify some problems inherent to the process.

As methodologies for waste elimination, primarily solutions were suggested based on the SMED method used with the purpose of reducing changeover time, the philosophy of the 5S that aims to improve the workplace organization and the Kanban method to manage and implement safety stocks, assuring continuous flows on the production. Next, the poka-yoke method to avoid occurrence of errors and mistakes during the production by mechanisms.

Finally, it was possible to verify the potential of some solutions through obtained results as well as to suggest further potentials.

2. Cutting Edge

2.1. Historical Perspective

Although beginning and duration of the Industrial Revolution vary according to different historians, the Industrial Revolution was a huge process of economic-social transformations that began in Great Britain around the eighteenth century, which within a few decades spread out to Western Europe and the United States. The transition process involved the change from the productive main activity, through handmade or use of simple machines up to replacement of human energy by driving power and manufacturing production systems. [1]

Around 1910 the first concepts of mass production emerged in the USA. Henry Ford had implemented large-scale production of standardized products, through assembly lines. He was the sponsor of the development of mass production trough assembly line techniques, developing the first production line to automobile that many middle-class Americans could afford. This method allowed achieving high percentages of production per worker lowering the current prices on the market. However, this kind of production revealed itself as not flexible: its work methods were largely inflexible which led to a situation where customers' wishes and freedom to choose could not be reached. Another weakness was the huge problem with quality revealed on products manufactured in large batches: detect a defect could happen only after a big amount of produced units. [2]

In Japan 1955, Taiichi Ohno and Shigeo Shingo had the task of developing a new production system for Toyota Motor Company at the Nagoya facilities. During this time, these two engineers combined various concepts from Asian religions and philosophies with the best existing concepts of production, predominantly American. They began to embrace Ford production and other techniques solving its inconsistencies and weaknesses: noticing the essential role of building inventories; bringing product variety; enriching the value of the employees by developing the teamwork mindset; and the concept of cellular manufacturing. Their work of studying setups and changeover problems produced great results on reducing setups to shorter times as well as allowing small batches on a remaining flow and giving flexibility to the system. The productivity and quality gains were so high and evident that the success quickly spread out. [3]

In contrast to mass production, the Toyota Production System was based on a continuous production flow without being dependent on long production cycles nor high stocks to be efficient. [4]

2.2. The Present

Companies face daily challenges in seeking innovation and flexibility to respond to a more diversified and demanding market by pursuing low prices with high quality, and at the same time in an increasingly sustainable perspective. [5] In order to maintain the quality of their products and services those constraints need to get over faster due to the high market dynamism. It is necessary to define strategies for growth, productivity and profitability without the need of big investments. Otherwise, companies might take the risk of not meeting the new market requirements. [6]

2.3. Lean Philosophy

In Lean philosophy key elements like continuous improvement and the pursuit of perfection must be a part of a daily company business culture. The same should be followed by its employee's routine, operating and creating value based on best process quality without waste. Just like all methodologies, Lean methodology must be correctly implemented to have an impact. [7]

2.4. Lean Manufacturing

Lean manufacturing emerges as an alternative to Lean thinking for companies that strive for cost reductions without changing the underlying management and thinking, searching for operational excellence and cost reductions on associated processes. [8]

According to Ohno´s model, those are the seven generic wastes: over-production against plan, waiting time of operators and machines, unnecessary transportation, waste in the process itself, excess stock of material and components, non-value-adding motion and defects in quality. [3]

A last one extends Ohno´s wastes: under-utilized people. [9]

2.5. Lean Tools and Methodologies

2.5.1 OEE

The equipment losses are the result of many sources, such as activities that consume resources but do not mean a benefit for the final product. In this context, Nakajima (1988) introduced and developed the Equipment Overall Efficiency model named OEE. OEE is a performance indicator used as a tool for measuring the equipment efficiency. In the introduction of this model, six basic types of waste were grouped into three main pillars that are fundamental to the proper work of an equipment: availability, performance and quality. The OEE value is calculated by multiplying those three factors. [10]

2.5.2 Time Study and Work Method Analysis

The majority of workers is paid for their time spent on the job. Consequently, labor time costs are often a major factor on the total product or service costs. Thus, it is important to know how much time is required to accomplish a given amount of work. In this context, work study emerges as an important tool to examine the various factors affecting productivity and finding answers to them. It is also a generic term for two techniques: method study and work measurement. Work measurement represents the required time record to accomplish given tasks establishing its standard time. Method study is related to examine and record systematically the way tasks are performed to find possible improvements. [11]

2.5.3 SMED

SMED was developed by a Japanese industrial engineer named Shigeo Shingo with the goal of reducing changeover times in companies. [12]

In SMED, changeovers are separated in two kinds of elements: internal elements that must be completed while the equipment is stopped and external elements that can be completed while the equipment is running. The core of the SMED methodology is to convert as many changeovers steps as possible to external elements, simplifying and streamlining all elements following three operational phases: (Phase1) Measuring changeover times/ identifying internal and external elements; (Phase 2) Reorganizing elements as possible to external; (Phase 3) Shortening internal and external elements & standardizing and maintaining new procedures.

2.5.4 Kanban

Kanban is a Japanese word which means "visual signal" and represents a visual method for controlling production. One of the key points of using Kanban is to reduce the amount of multi-tasking. Kanban allowed companies to use "just-in-time" production and the possibility of ordering systems, minimizing their inventories while still satisfying costumer demands. [13]

2.5.5 Poka-Yoke

Poka-yoke is a Japanese term and it means "mistake-proofing". In Lean manufacturing, poka-yoke can be represented by any mechanism that helps equipment and operators to avoid errors and mistakes, removing product defect before or when they occur. This poka-yoke concept was formalized by Shingo. [12]

2.5.6 VSM

VSM is a visual method which illustrates graphically how material and information flow to deliver a product or service. It is composed in three distinct regions: Information Flow, Process Map and Timeline using a set of unique symbols to visualize the process. With the help of this process, visualizing weaknesses or bottlenecks areas can be found and organizations are driven to improve and make the necessary changes. [14]

2.5.7 5S Method

5S Method is defined as a methodology for continuous improvement in order to get a safer, cleaner and more enjoyable workplace. It represents five Japanese words that describe the steps of a workplace organization process: Seiri (Sort), Seiton (Straighten, Set), Seiso (Shine, Sweep), Seiketsu (Standardize) and Shitsuke (Sustain). [15]

2.5.8 The 'Five-Whys' Method (5W)

The 5W method is a technique to find the root causes of a problem. The method consists of starting to ask 'why' the problem occurred and then continually asking 'why' again as a reaction to the response, repeating the procedure 5 times or until it is difficult to find an answer. [16]

3. Applying Lean Manufacturing – Innovate Wet Wipes Production Line 2

The main goal of this study is to apply Lean Manufacturing tools, concepts and methodologies in a production line belonging to the company Innovate Wet Wipes aiming to search for higher flexibility, efficiency and productivity.

After understanding the production lines of the company and its respective products, the entire current state of the production system was analysed by historic and collected data on-site and its respective OEE values calculated.

According to the acquired knowledge and research results, a specific production line was selected where the root-causes of problems were diagnosed, analysed and solved. For that, strategies and Lean tools have been used to reduce or eliminate them.

3.1. OEE

After getting to know the company and understanding its global operation process and production lines, a parallel analysis was carried out to pick a single production line to focus on in this study. By calculating the overall OEE value on each production line based on daily data like production plan, expected performances, operators' daily reports and its respective outputs, it was possible to obtain an overview of the entire production and to identify potential improvement.

3.1.1 OEE on each Production Line

The company operates in two shifts (8 hours each) and the daily production of each line was considered to calculate the OEE indicator that is a result of multiplying three factors: Availability (which a line actually produces and does not stand still due to e.g. breaks, changeovers or defects); Performance (determined by the ratio between final and planned output target while the line is working without any interruption); and Quality (calculated from the ratio between good and total produced goods).

During the 4 weeks study, no maintenance was carried out and data was collected to calculate daily OEE values for each one of the six production lines. The reached average values for each line were then summarized thus allowing to have a global view of the entire production and to understand which line has the lowest value, Figure 1.

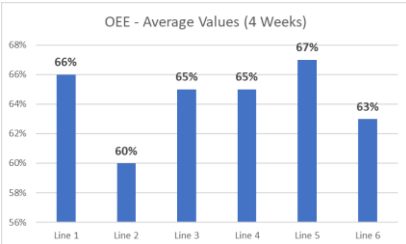

Figure 1 - OEE applied in all production lines

Thus, after gathering the knowledge acquired “on the field” and getting a global overview over the production lines efficiency, Line 2 was strategically selected. Besides its lowest efficiency value of 60%, it is also the least automated line and has accordingly a high dependence on workers.

3.1.2 OEE on Line 2

Figure 2 shows how calculated OEE values and its respective factors varied during the study period.
By analysing the graphic, the factor quality has a small impact on the line efficiency (89-99%) which may be explained by the possibility of repacking wet wipes.

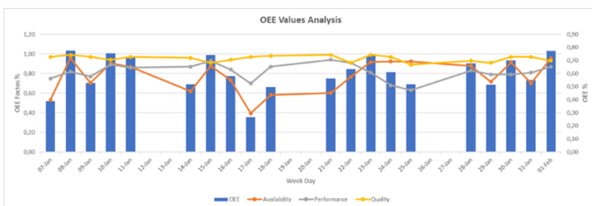

Figure 2 - OEE values Line 2 (4 weeks)

Regarding to the factor performance, there are clear variations which are directly influenced by speed-loss and short-stop times which are mostly related to the high dependence on workers: a lack of material connected to workers was also considered as stop time, Figure 3.

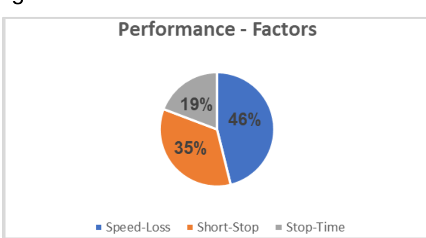

Figure 3 – Performance factor (OEE)

Availability, besides instable is predominantly the lowest of all the 3 parameters and thus having a greater impact on Line 2 efficiency. All the lowest values were associated to full or partial changeovers.

In summary, not only the experience in the field but also the performed analysis of factors such as lower productivity, greater dependence on operators and product specificity and the lower OEE value, led to the choice of Line 2 for this case study.

3.2. Case study (Line 2)

3.2.1 Production Stages

The production in Line 2 follows specific stages until the product (wipe package) is finished and ready to send to the client:
Stage 1: Pallet with dry wipes stacks: an operator brings the material stored in a pallet containing dried wipe stacks on plastic boxes. The pallet is transported to the line.
Stage 2: Introduce Wipes Stack: an operator grabs a dry wipe stack pile and introduces each stack in a diving Machine.
Stage 3: Diving/Press Machine: the dry wipe stacks dive into a lotion bath and are pressed to remove lotion excess.
Stage 4: Packing Machine: Wet wipe stacks are moved into a packing machine to be sealed.
Stage 5: Metal Detector: Check the presence of metal elements inside the packages.
Stage 6: Weight Checker: Check packages weight.
Stage 7: Turning Packs: Turn packages down-side-up.
Stage 8: Lid Robot: A robot glues the lid on the packages top.
Stage 9: Pack the Cartons: An operator picks the packages and puts them into cartons.
Stage 10: Palettizing: One operator grabs the taped and printed cartons and assembles them in pallets.
Stage 11: Stretch Wrap: When pallets are finished, a plastic layer is used to cover it.

3.2.2 Time Study and Diagnosis

Values that represent the production line reality are quantified which are the result from instant observations and timing. According to the obtained data it was possible to check eventual improvement points and constraint stages.

3.2.2.1. OR

OR is a KPI that allows to see which stages are overloaded: relation between total production time and available working hours.
According to the production data and assuming those values represent the global production, it is possible to know the average of packages per day: 16000.
By timing it was possible to determine the average cycle time values for each critical stage: not all the different stages were measured because not all of them are influencing the producing pace, Figure 4.
To calculate the OR, rejected products are also considered because it is also necessary to spend working time even though the product does not reach the final consumer. According to the recorded production data, Line 2 has shown an average loss of 0.88% on rejections from Metal Detector, 4.48% in the Weight Checker and 2.64% in the packing of cartons.

In this way, it is possible to calculate the OR values and find the stage that is working close to its limit to produce the total amount of daily packages, Figure 4.

Stage	Family	Tc	NWP	AWH	NH	%OR
2 – Introduce Wipes Stack	1	2.9s	1	16	13,98	87.39
9 – Pack the Cartons	1	2.3s	1	16	10,5	65.62

NWP: Number Working Places
AWH: Available Working Hours (2 shift-system)
NH: Number of Hours
OR: Occupancy Rate

Figure 4 - Occupancy rate in Line 2 (critical stages)

Analysing the obtained OR values both stages are operating near the limit to accomplish the daily quantity. However, the highest value is found in stage 2 where the operator's performance is directly related to the production rate. This means that the line is running near the limit and has no capacity to react to new or higher orders. Perhaps some improvements can be done to improve the rate on stage 2. However, to intend an increase of the production on the Line 2 it is necessary to check if there is waste that can be avoided or even eliminated: in particular waiting time and changeover time.

3.2.2.2. Studying Line 2

To elaborate this analysis, instant observations were done to record the different phases of production, allowing to reach the percentage time values and quantify possible losses, Figure 5.

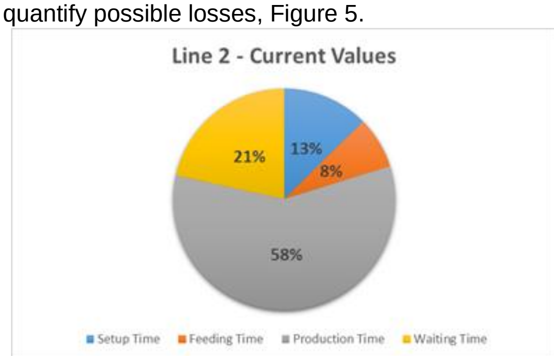

Figure 5 - Time study Line 2 (current state)

Four basic states to describe the production status were considered: Production Time (percentage of time the machine is producing); Waiting Time (percentage of time where the machines are not running even though they are ready for it); Feeding Time (percentage of time where the machines are waiting for the material); and Setup Time (percentage of time where machines are not running but are being prepared for the next production - changeover).
According to the results, only 58% of the time the line is producing and adding value to customers. The remaining slices are just non-adding value for the production: 13% Setup time, 8% Feeding time and 21% of Waiting time. There, waiting time is mainly related to employees' fatigue caused by the repetitive work on the diving machine while performing their job; punctual interventions like small adjustments on machines; and no available material in the Line (only due to dry wipe stacks).

3.2.2.3. VSM

To develop the study and describe the current production line state, a VSM was drawn aiming to have a better global visual representation of the material and information flow, Figure 6. Two relevant factors are calculated: Value Added Time that represents the operating time in which value is being added to the product and Lead Time, which is the total required production time since the raw-material arrives to the company until the moment that it is shipped to the client (Figure 7).

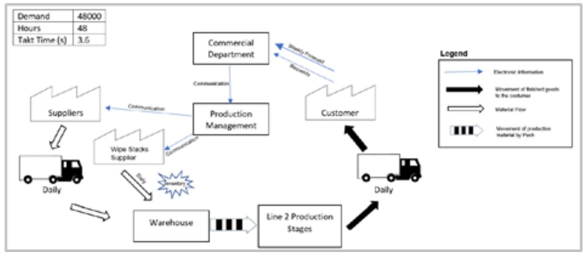

Figure 6 - Line 2 (VSM – current state)

The commercial department is responsible for the communication between the company and costumers. It is where future goods forecasts are predicted and customers' requests are replied to. As soon as everything is strategically decided the information is given to the production management that has the responsibility to spread and organize the production. Thus, raw materials are daily received in the warehouse from where they proceed to the respective production line and stages, being finalized and ready to send to customers.

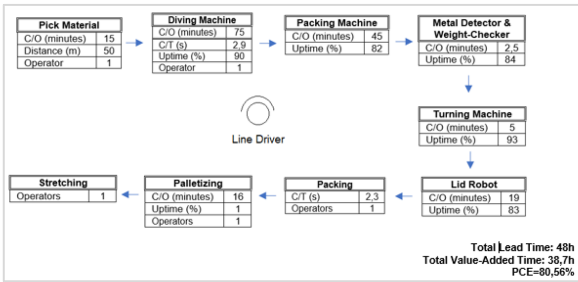

Figure 7 - Line 2 production stages (VSM)

As shown in the VSM Figure 7, the calculated lead time value is almost the same as the value-added-time. Assuming the material is already waiting in the warehouse, the lead time is only affected by the production run efficiency, which eventually explains the relatively high value on process cycle efficiency (PCE): the ratio between value-added time and Lead time. Thus, it is important to understand if eventual improvements can be performed to ensure that material is always available (Figure 6), avoid as much non-value-added time as possible during production and check all the changeover process (Figure 2) which led to lower OEE values. Find possible improvements that avoid bottlenecks on the different production stages, namely where the OR is near the limit (Figure

4) and Feeding-time when the operator has no capacity to feed the production line continually (Figure 5).

3.3. Diagnosis and Solutions

3.3.1 The 5W

While studying the times (Figure 5), it was observed during changeovers that often too much time was spent on unnecessary motion, namely searching for information once workers frequently had to leave their workplace. The root cause was not clear and to dig into it an analysis through the 5W method was performed. By questioning “why” it was identified as a root cause that there was no quick and effective communication between actors who were not in the same zone. That could be solved with the help of a communication system.

3.3.2 SMED

During direct observations and experience on the field it was diagnosed that changeover processes were mostly performed without standards, which indicated a potential focus for improvement. For that, the SMED methodology was considered which aims fast and efficient tool change, optimizing operator steps for changeover, as well as all the operations included in the process. In this case, it is not a single tool but the complete line setup for a product change.
Initially, the necessary procedures were written down and its respective spent time recorded. After this first step, the process then undergoes 3 phases: Phase 1 to split operations between internal (machines cannot run) and external; Phase 2 to change internal into external procedures; and finally Phase 3 to define new operating procedures to reduce internal and external times. Thus, after applying the SMED methodology new times are reached contributing for a better operational improvement. Regarding to internal operations a reduction of 27% is estimated, which is mainly related to a standardization in the process and a clean and organized workplace (5S method).
Referring to external operations a reduction of 87% is estimated which is mainly associated to communication and organization problems mostly spent on motion, Figure 8.

Tasks	Measured Time (Current)	Estimated Time	% Total Time Reduction	Operation
Confirm the end of production	00:03:35	00:00:30	86.05%	External
Pick new Product Specification & Write Protocol	00:15:25	00:00:00	100.00%	External
Check Specification and ask for the new Material	00:02:50	00:00:55	67.65%	External
Ask for Hot Water	00:08:35	00:00:00	100.00%	External
Water Test	00:05:45	00:00:00	100.00%	External
Ask for Lotion	00:07:42	00:00:00	100.00%	External
Feed Packing Machine with Film 1 Roll	00:08:00	00:04:00	50.00%	External
Set Cartoon Printer & Tape Machine	00:08:00	00:00:00	100.00%	External
Call Quality and Write the Quality Protocol	00:14:00	00:04:12	70.00%	External
EXTERNAL OPERATIONS	**01:13:52**	**00:09:37**	**86.98%**	

Figure 8 - External operations (SMED)

The analysis represents the worst possible case which occurs at least weekly. Thus, a reduction of 47% is expected on changeover times, Figure 9.

Tasks	Total Measured Time	Expected Time	% Total Time Reduction
Complete Change-Over	03:37:33	01:54:57	47.16%

Figure 9 - Estimated reduction (after SMED)

3.3.2.1. New Process Dynamic

Through field experience and while performing a more detailed analysis through the SMED method, it was detected that too much time is wasted on actions such as requesting or searching for information. That led to longer changeover times and a surplus work compensated through unnecessary workers movements. Thus, in order to understand the root cause of the problem, 5W methodology was used diagnosing inefficient communication between actors even though they are almost in the same zone.
As a possible solution for this problem, the use of a communication platform was proposed to prevent the operators to leave their workplace and if possible, where information can be easily and quickly achieved and visualised. In this way, the idea of developing a communication platform emerged with the purpose to create a fluid process during changeovers to avoid unnecessary movements, manly performed by the line driver, Figure 7.
During the production, the line live-status is available on two big screens connected in a data-bank (master): one screen is placed in the packing area and another one in the production area. In this master, five tablets are connected via Wi-Fi and can interact among each other. These five tablets are distributed between the operators who are responsible for the changeover process, Figure 10.
On these gadgets information like the current speed of the line, required material and the forecasted end of production are available.

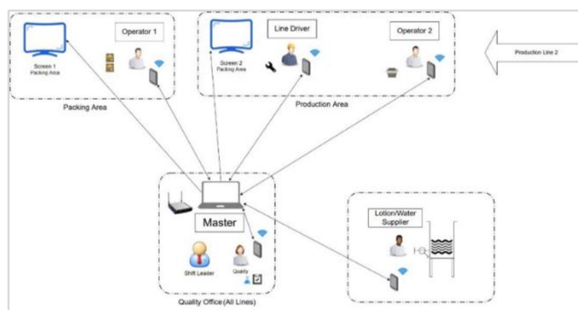

Figure 10 – Shopfloor communication platform

Briefly explained, the communication platform for Line 2 would consist of six operator’s interactivities: shift leader (master), quality worker, Lotion/Water supplier, operator 1 (forklift operator), Line Driver and Operator 2 (responsible for supplying material to Line 2), Figure 10.

3.3.2.2. Cost Analysis SMED

After applying the SMED methodology, some solutions were elaborated and described. To verify the feasibility of the proposed solutions, a cost analysis was performed. The associated costs for the required tools, material and the implementation of a communication platform prefaced a value of 9062.33€. In accordance with the estimated weekly profit, that investment could be amortized in 8 weeks. Thus, the gains are considerable and its expansion to the other lines can be considered.

3.3.3 Kanban Method

Currently, the company is getting dry wipe stacks based on costumers' demand but only shortly before the production on Line 2 takes place. As already mentioned, the dry wipe stacks production is done in another facility of the company as represented on VSM (Figure 39). When Line 2 is running, most of the time dry wipe stacks are still being produced to comply the production. This approach has its limitations and goes beyond the just-in-time. Thereby, it was marked on the VSM diagram as a point to take into account: once a problem occurs on the dry wipe stack supplier, the non-existence of safety stocks consequently slows down or stops the production on Line 2. In the worst case, even leading to a non-expected and premature product change.

In this perspective, the idea to apply the Kanban method came up, which intends to promote a pulled production rather than a pushed one. In this case study, it is intended to reach shorter lead times by avoiding a lack of material by means of creating safety stocks, reducing unnecessary stocks and improving the communication between the sectors.

3.3.3.1. Kanban Cards

Plastic boxes are used to store produced dry wipe stacks. When filled up, those boxes are then piled in pallets and its amount identified and everything is performed according to what the dry wipes stacks supplier can produce: either until the end of raw-material, machine problems or finished demand.

A change of the philosophy of production is proposed by creating and keeping safety stocks. Consequently, it is important to build a system that leads to the production of safety stocks, keeps the stocks above a minimum level and controls the necessary stocks to produce. Thus, it is important to avoid a lack of material, production stops and no precise control or overload of the amount of wipe stacks.

Therefore, it is necessary to use a detailed Kanban card (Figure 11) with information to produce a given lot of wipe stacks. In this study, each Kanban card represents a complete pallet.

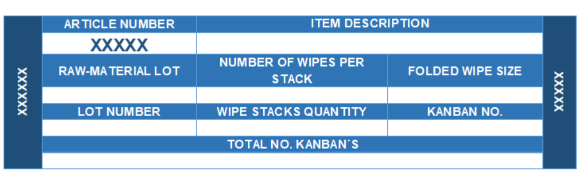

Figure 11 - Kanban Card

On this new approach, a pulled production system is implemented where only the customer can request the entry of a Kanban into the production system by starting the production of new goods, or new lots of products. These cards also define the urgency of each request. For that, two types of Kanban are suggested: green and yellow ones. Whenever a yellow one has been set, it should be taken into consideration for the next demand. Thereby, the yellow one is the point where the stock of the material is under the limit, which needs to be compensated the next time or when the supplier has some production freedom.

The necessary number of Kanban cards is given by a formula (Figure 12) and depends directly on the number of packages the customer demands as well as lead time and a safety factor:

On average, Line 2 produces 16000 wipe stacks a day and the lead time to obtain that amount of wipe stacks is 3 days (VSM map, Figure 7). The safety stock in percentage is 8% to compensate process average wastes. Each pallet contains 1080 wipe stacks. Thus, there are 48 Kanban cards presented in the system.

$$N = \frac{DT(1+X)}{C}$$

N- Number of cards
D- Daily Demand
T- Lead Time (in Days)
X- Safety Stock
C- Quantity in a Container

Figure 12 - Kanban lot sizes (formula)

3.3.3.2. New Process Dynamic

To calculate the necessary number of Kanban cards, an average output of 14400 on wipe stacks supplier was included considering its historical data. To dimension the safety stock amount, it was considered that Line 2 and the wipe stacks supplier have the same changeover time which is a good approximation: a faster changeover on Line 2 can be performed in one hour while on wipe stacks supplier one hour is the average changeover value. Therefore, lead time is given according to the waiting time in Line 2 in case of no safety stock and start at the same time. Considering this situation, 10 Kanban cards must be added to the system. Thus, it is necessary to implement a new system dynamic, Figure 13.

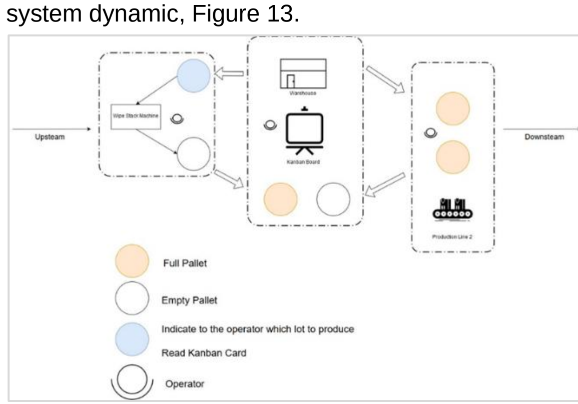

Figure 13 – New process dynamic (Kanban)

The pallets with dry wipes stacks are produced and fixed according to client demands (Kanban Cards, Figure 11), consequently implementing a pulled production where the warehouse plays the main role by managing the Kanban cards and following a specific dynamic, Figure 13.
The warehouse manages the Kanban system where it is extremely important to work synchronous with the commercial department and the production management.
By receiving a new customer demand, Kanban cards will be placed on the position “Demand”. Once the new demand takes place, the cards on position “Safety-Stock” are sent to “L2” and the cards on position “Demand” are given to the dry wipe stacks supplier to start its production. This is where the crucial phase lies: under each product name, an area will signal if the stock is below the indicated. If so, the order to be sent will be higher to restore the stock in safety level again, Figure 14.

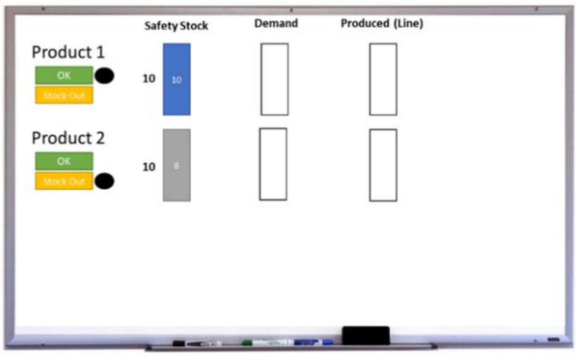

Figure 14 – Kanban board

By using this Kanban system, it is expected to assure the production in Line 2 as long as the product stock levels are kept. However, once the Safety Stock is reached (yellow “Stock Out”), a mark signs that it is necessary to replace the stock. Otherwise, it will lead most likely to waiting times on Line 2.

3.3.4 Poka-Yoke

In lean manufacturing, poka-yoke can be represented by any mechanism that helps equipment and operators to avoid errors and mistakes.
On the production Line 2 at the diving machine stage, an operator is responsible to give the production pace by introducing dry wipe stacks. To have a constant and smooth process, the packing machine is configured for an average speed with up and down acceleration tolerance, so that the line continuously produces. Unfortunately, due to operator fatigue/impatience speed fluctuations occur that lead to stop times or in the worst case, line congestions when the operator is too fast.
During the time study (Figure 5), waiting time is partially due to wipe stack that got stuck between productions stages that led to stops. Two bottlenecks are found: Stage 3 and 4. There the operator's visibility field is reduced.
To overcome the problem, a sound alarm is suggested in this study to mark the precise pace for introducing wipe stacks as well as two fixed cameras to allow the operator to see what is happening, Figure 15.

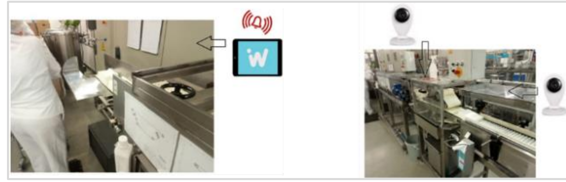

Figure 15 – Poka-yoke Line 2

3.3.4.1. Cost Analysis SMED

To solve the problem when wipe stacks got stuck, it normally led to stop times never less than 10 minutes. In worst cases even parts of the machines had to be disassembled to remove all the wipes safely.
The required material to implement the proposed solution is quite low and prefaces 297,57€. According to the recorded time spent on cleaning and since it happens minimum once a day, the investment should be amortized in less than a week.

3.3.5 Other Solutions

During the time study, weight variations in the product happened. By examining the wet wipe stack inside of each rejected package, it was observed that the wipe stacks did not have a brick shape.
To solve the problem, the operator always adjusted the upper and down conveyor speed on the diving machine, until reaching the perfect shape: both conveyors had no longer the same speed, creating unstable shapes. Thus, by performing the 5W method it was diagnosed that the root cause was the friction between shafts and conveyors. Another shafts surface texture is suggested to create a rough texture on all shafts to create a higher friction between the conveyor and shafts.
However, the conveyor needs to be changed from time to time and it was diagnosed that no scheme was available: when removed, the operator was no longer sure about the correct way to set it through the shafts. Therefore, a drawing was required where the operator could easily see it.

4. Expected Improvements on Line 2

4.1. Production Time

After studying the line through lean manufacturing tools and methodologies, improvements regarding to times are expected, Figure 16.

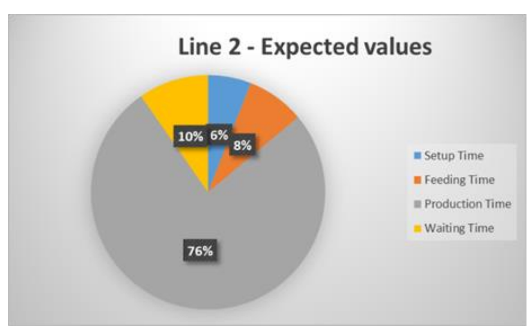

Figure 16 – Expected values Line 2

Comparing the previous obtained values (Figure 5), the setup time might experience a reduction of 47% after applying the SMED methodologies due to a shorter changeover time. The new time is achieved by implementing new standards and procedures in the organization leading to more efficient and quicker decision processes.
Waiting time (mainly associated to employees' fatigue on the diving machine, punctual line driver interventions in some machines belonging to the process and no material in the line) will eventually have a reduction of 55%. This reduction is mainly related to the developed poka-yoke system and to the new process dynamic implemented by Kanban cards. However, the time related to the line driver machines interventions will remain a great cause of waiting time.
An improvement for the feeding time - associated to the operator who supplies the line with dry wipe stacks - is not so easy to handle. Once the operator is responsible for other lines, times can occur in which the material might fails to work in the manual loading conveyor or, in the worst case, there is no material available on the line. However, a better organization between operators can reduce the problem.
Therefore, the production might reflect a sustainable growth up to 76%.

4.2. VSM-Future State

In this study, some changes of the company's organizations are suggested with the purpose of a faster and efficient flow, either focused on material or information flow (VSM, Figure 6). Therefore, it is suggested to implement safety stocks on the wipe stacks provider which are managed according to the demands of the production on Line 2, Figure 13.
The supplier of raw material will be shipping to the warehouse daily. In this case, the necessity of having stocks is not mandatory. Its dimensions and consumption rhythms give flexibility to daily shipments. The only condition is to purchase the material to arrive having enough time before it is required in production: mainly packing film rolls and labels. According to these factors, it is suggested that the managements of raw materials must be done by the warehouse, Figure 17. There, experience on production consumption is an acquired knowledge. Therefore, it is expected to have a better efficiency on the buying procedures without misunderstandings between warehouse-production and management-commercial department.

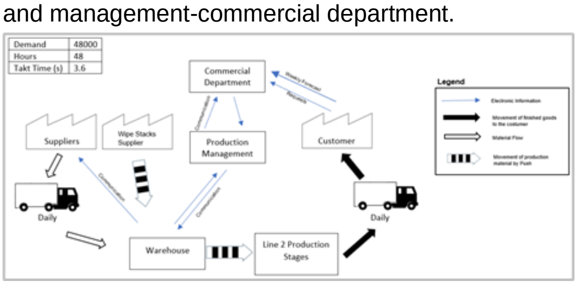

Figure 17 – VSM future state (Line 2)

Considering this, commercial department and production management would work as one. The commercial department focused on answers to customers and production management with the central role of checking the productions line availability and perfect planning, while choosing products that are similar to shorter changeover times: products and its similarities are the key to success on implementing this new production system approach. Usually, products are selected in a non-productive way causing delays on changeover. One example are products with different lotions which require a lot of time cleaning the line. Some lotions are so difficult to wash that the use of hot water only is not enough to remove it.
In this way, it is expected to improve the lead time as well as to give more capacity and organization to the company.

5. Conclusion

In this study. the production Line 2 of the company Innovate Wet Wipes was analysed based on the elaboration of diagnosis to identify critical points and present possible solutions for them.
By the application of Lean manufacturing tools and methodologies, some problems were identified, namely production problems caused by reliance on operators, nonexistence of controlled stocks and inefficient communication between planning and controlling the production activity. Along with this, the time spent on motion in search of information and its confirmation was causing longer changeover times.
With the suggested solutions, it is tried to deal with the problems in an objective way and to bring a new behaviour for the responsible workers on the production line building up a new concept of work.
According to the analyses performed by means of SMED methodology (section 3.3.2), the entire changeover procedures on production Line 2 were written down and its respective time spent was recorded. Over splitting all the procedures and organizing them into ones which required stopped production and not, it was possible to rearrange and work individually in each one, gradually decreasing changeover time. With the obtained results, a substantial reduction on the final setup time is confirmed, contributing to an increase of flexibility in the line, whenever a changeover is necessary. The production will not stop for so long which leads to a continuous material flow and less waiting times.
To control all the necessary steps on a changeover and to simplify communication between workers, it is intended to have more information about the inherent process on the changeover and a better perception from the times spent on each (recommended communication platform, section 3.3.2.1). In this way, useless motion times are eliminated, encouraging a better work organization to each sector directly or indirectly linked to the production line. Despite timed tasks, the responsible persons can directly interact and they are forced to act as well as to provide fast and effective communication. Workers, the company and customers benefit from this.
Concerning the Kanban method suggestion, on section 3.3.3, it is intended to completely change the way of producing dry wipe stacks. Through an effective

communication between production on Line 2, warehouse and dry wipe stacks suppliers, it is possible to generate safety stocks, boosting the production driven by the customer's wishes, which regulates the existing stocks. That promotes a continuous material flow and streamlining all production dynamics.
Poka-yoke (section 3.3.4) is suggested as an effective control tool to avoid mistakes that might occur due to operator fatigue, recognizing and avoiding errors that are part of being human.
The solutions proposed in section 3.3.5, are a perfect example of the finding that simple things can improve the process significantly. By detecting problems and investigating their causes as well as working out possible solutions.
With all these solutions, it is expected to contribute to a higher flexibility on the production Line 2 due to a shorter changeover time, an effective communication level and a better process flow balanced on stocks by implementing a pulled production system.
A production system with less waste of time and shorter changeovers is an asset that results in a productive and competitive company.
Given the complexity of factors affecting the efficiency of production lines, it is possible to do more detailed studies on various aspects. However, the pursuit of simple and efficient solutions is the company's goal. In this way, the study is focused on situations that are considered most relevant, in an objective way, so that it has the maximum practical usefulness.
During the work time at Innovate, it was possible to identify many detailed solutions that proved to be efficient in their application.

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