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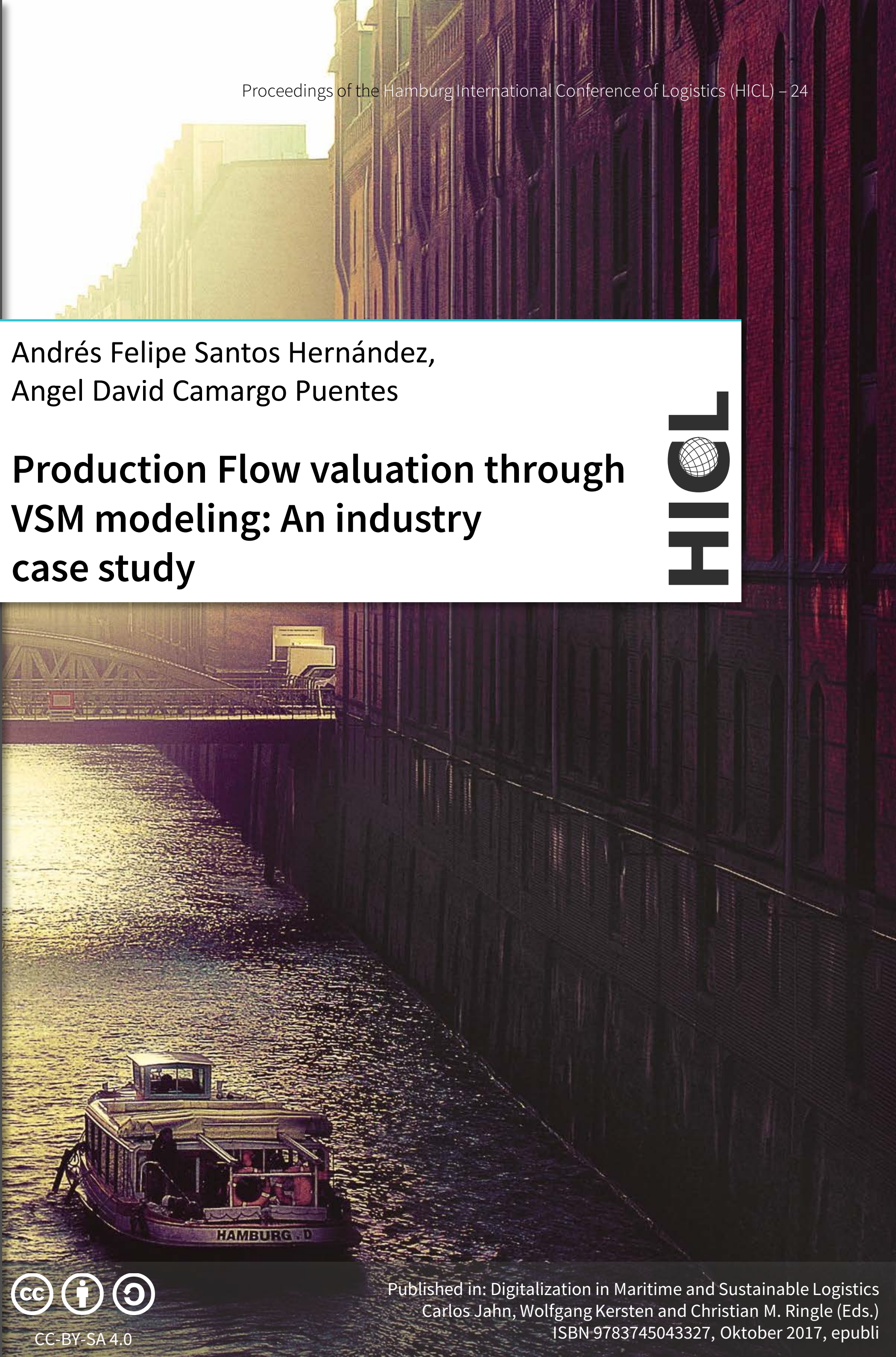

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Production Flow valuation through VSM modeling: An industry case study

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A special combination of lean methodologies and modeling of industrial processes has been increasingly used in the last decade between University and Industry. With lower costs, knowledge in lean tools and innovation in simulation packages, manufacturing has improved its practices in the flow of their processes detecting aggregate value. The research team describes a case in which a glove manufacturing production line and its Value Stream Mapping are simulated at the same time. The purpose of this work is to identify potential benefits such as reducing waste, improving lead time, resource optimization, reduced WIP and increasing throughput by simulation, applied to a real case industry. The modeling of the process and its VSM as a visual tool, highlight waste and hidden sources of the same through the variables and their behavior in the development of the simulation. Via a first simulation, the current process status is diagnosed. Then, using LEAN-manufacturing tools, a proposed VSM model is designed, which, through indicators and plots, shows the elimination of the causes of waste and improvements of this process.

Keywords: Lean; Lean logistics; CONWIP; Little law

1 Introduction

During this time, specifically in the industrial sector, there has been an interest in greater efficiency in all processes, such as operative, logistic, or administrative processes, focused on adopting the best practices in order for the proposed option to be feasible. To achieve the main goal, which is to obtain high efficiency in processes, the organizations have adopted methodologies that allow for the visualization and control of all the necessary steps or processes in order to carry out certain tasks, and among these is the LEAN methodology. It allows us to reduce or eliminate waste or activities that do not generate value for the organizations (Abdul Malek and Rajgopal, 2007).

The LEAN methodology is being adopted by organizations, on a global scale, in order to enable them to increase their competitiveness in a national or global market. The promoter for this methodology was TOYOTA, and was championed by different associates within the administration and handling of the quality department in the organization, such as Toyoda, Taiichi Ohno, and Juran. As the first tool, it began with TQM initiated by Deming which has promoted from its beginnings waste disposal and activities that do not generate value in the processes of the company. During this time other tools appeared, such as the TPM, VSM, SMED, and JIT(Muhammad al-Ashraf, 2012), (Jones, Hines and Rich, 2001), (Wu, 2002).

In the event simulation area, they have raised analytical, but not graphical simulations, focusing on algorithms and visualizations of its processes and how they are being carried out, a simulation definition can be the approach to a real event by means of visual methods, combining it with statistical and mathematical tools. By using hardware, such as the PROMODEL, it can offer us a more detailed approach of the reality and therefore promote action plans to improve the identified activities that do not generate value (Harrel Gosh, 2000).

This work has the goal of using PROMODEL, in order to carry out a latex glove production process simulation case study, applying LEAN through value stream mapping tool. The purpose of combining the previously mentioned software was to analyze all the productive stages from raw material requisition until product delivery to the final client.

2 Methodology

2.1 Data Collection

In order to improve the process and cause significant impact on the financial indicators, the research group identified the product to evaluate, through a Pareto assessment. From the annual income, 18% corresponds to the “C25 bicolor Industrial Glove”, a high turnover product. Keeping the selected product in line, the process was assessed in close observation for three weeks, in order to identify the practices and identify potential waste. In this same period, transportation, flow and delay data was collected. Additionally, procedures, formats and standard working methods were reviewed. Statistics associated with process were compiled in the production planning and control stages, with a record of 4 months between their respective analyses.

2.2 The VSM Tool

In order to use the LEAN methodology, 5 principles must be taken into consideration, which were proposed by Womack (2003) in order to apply the philosophy, which are:

1. To define value in the eyes of the consumer
2. To identify the flow or the chain of value
3. To generate a continuous and smooth flow from the provider to the consumer
4. To allow the client to pull the product (PULL)
5. Continuous improvement in order to achieve perfection.

These 5 principles describe a short definition of the VSM mapping, but the essence of the VSM is about eliminating all the waste and non-value operations that influence the costs of the organization (Lasa, Laburu and Vila, 2008). This can help us to identify and solve the different problems of the supply chain, or another process being analyzed (Hines and Rich, 1997).

These 5 principles shortly describe VSM, but its essence lies in eliminating waste and non-value operations which affect the costs of the organization ((Lasa, Laburu and Vila, 2008). This can help us identify and solve different problems within the supply chain or other analyzed processes ((Hines and Rich, 1997).

3 Case Study: The Process

3.1 Company and Progress Background

The company being analyzed is part of the Confederacion Cauchera Colombiana (CCC for its Spanish acronym), which has been recognized by the Colombian Ministry of Agriculture and Rural Development as the national organization for the rubber and latex manufacturers since 2002. In 2015, with about 58 thousand hectares planted with natural rubber, only 20% corresponds to productive sections, which means about 5 thousand tons per year, with 25 thousand tons being consumed by the productive sector of the country; the other 20 thousand tons are imported from Brazil and Guatemala (CCC, 2016). Although crop growth has increased exponentially at a rate of 10% per year, production has fallen by 19% per year, due to price problems on an international level (MINAGRICULTURA, 2016).

The industry, and in general all its subsections exhibited a total growth of 2 %, as presented by the ANDI at the end of 2016. During 2016 the sector has had to face different problems such as the supply of raw material, infrastructure and logistics cost, contraband and tributary expenses.

The increase of these problems has affected the logistic competitiveness of the sector, and has caused an uncertainty regarding what could happen to the market. In order to change alternatives, there is a tool that allows us to visualize and identify each of the links that compose the supply chain and how they individually influence the identified problems or the chain in general.

Given the shortage of domestic raw materials, the complexity of importing materials and low price products from China, management has chosen lower costs associated with glove manufacturing in Colombia.

With 7 productions systems, the industry in evaluation obtained a turnover in 2015 of close to US $ 1.2 million. According to management, it was decided to study the system 1 given that it employs the latest equipment and with better speeds. To select the product to be evaluated, a Pareto was constructed on 15 product references that were currently processed. Within the gloves there are different calibers, colors and destinations of use. The Caliber 25 two-color industrial glove was the first product of the type A family, representing 17.8% of the income with US $ 186,000 per year. Of this product 5 sizes are produced: Size 7 with a 5% participation, size 8 with 24%, Size 8.5 with 5%, size 9 with a 52% participation and size 10 with a 14% participation. According to these percentages in the monthly production, proportional inventories of the molds are maintained.

Management found the LEAN philosophy to be the strategy to generate greater added value to its consumers with a rational use of resources, improving planning and control of the operation in coherence with prices and market demand. This research, through process simulation and VSM, will allow management to compare productivity of the current system and a system under LEAN parameters (Calva, 2014).

One of the tools that enable us to realize what we propose is the VSM, or Value Stream Mapping, this tool allows us to graphically visualize all the links that compose the supply chain and allows us to identify the individual bankruptcies (Lovelle, 2001).

Due to the help that this tool can offer, it is possible to apply to the industries of the sector and this way to diminish the suspense of the market and to match its needs more appropriately or to improve the processes that are carried out to obtain a few minimal logistic and financial cost savings.

3.2 Process Flow

In order to achieve the VSM, one emphasized the production of latex gloves, for which the production process fulfills the following steps:

The process begins with an operator preparing the mixture, this process takes about 8 minutes, once the mixture is finished, an operator from the immerse area, pours the mixture in the molds and another operator places the molds in the immerse machine. This process has 3 stages with a total duration time of 21 minutes, including adjustment after immersion, then the gloves are bordered by one operator in 18,7 minutes including the disposal of the gloves in a bin. This bin is the work in process of the process and then it passes to a conveyer belt in order to vulcanize the gloves in a FIFO line. Once this process has finished, the gloves move on to the de-mold process before being processed in extraction and chlorination operations. Finally, after they have been chlorinated in the bins, they are dried in a machine.

Process Flow Diagram				
Location	Plant of Gloves		**Summary**	
Activity	Manufacturing Glove Black-Green C25		**Activity**	**Actual**
date	18/08/2016		**Operation**	118,5
Operator		**Analyst:** A.C.	**Transport**	37,2
Method	Actual X Propose		**Delay**	22,4
Type	Operator Material X Machine		**inspection**	-
Comments:			**Storage**	-
Batch = 48 Gloves Black-Green C25= 224 min. / 4,7 min per Glove			**Time (min.)**	178,1
			Distance(mts)	32,2

Activity	Symbol	Times (minutes)	Distance (m)
1. Immerse in immersion system; tank black latex		6,5	
2. Lift molds and rotate system to the right		0,5	1,5
3. Immerse in immersion system; coagulant tank		7	
4. Lift molds and rotate system to the right		0,5	1,5
5. Immerse in immersion system; tank green latex		6,5	
6. Lift molds, remove covered molds		12,4	
7. Carrying molds to the conveyor belt		8,5	2,7
8. Take uncovered molds and take to the immersion system		6,8	2,7
9. Install bare molds in system		16,2	
10. Transport of molds covered towards the furnace through conveyor belt		15,4	12,0
11. Bordered gloves		18,7	
12. Vulcanizate the gloves in the molds		25	
13. Unmold gloves and turn		8,6	
14. Put gloves on bins		3,4	
15. Transport to the Extraction area		1,6	4,7
16. Gloves on bins, wait for extraction		22,4	
17. Extraction		5,6	
18. Transport to the area of chlorination		1,1	1,4
19. Chlorination		3,8	
20. Transport to the Drying area		1,5	4,1
21. Drying		8,2	
22. Transportation to the Cooling Area		1,3	1,6

Figure 1: Process flow diagramn

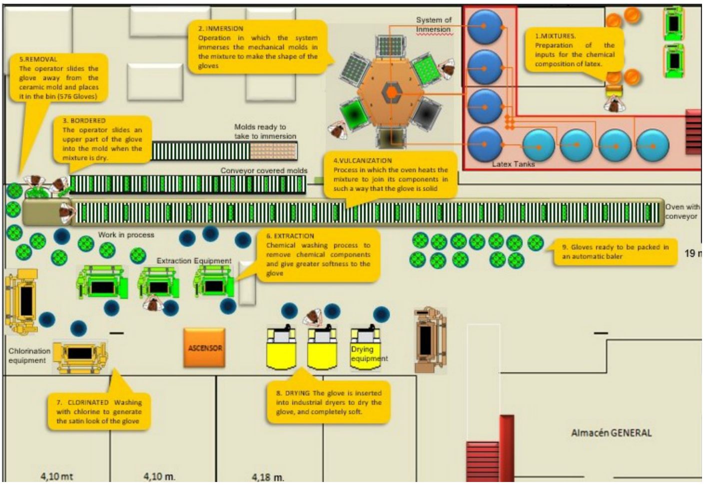

Figure 2: Layout and process

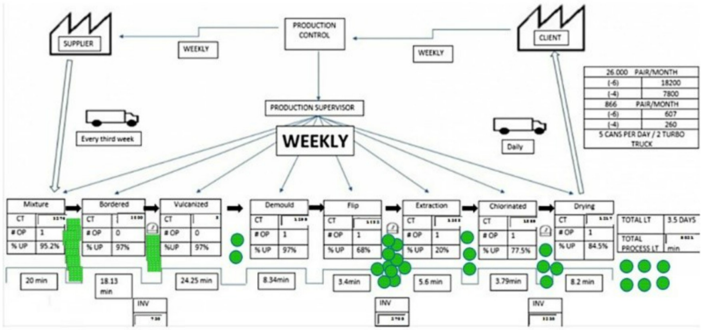

Figure 3: Actual VSM

3.3 The Actual VSM

Thanks to the data retrieved from the times and movements study, a simple flow of production line 1 has been made, which refers to the C-25 latex gloves, with the starting point being the reception of the raw material that is suggested for the product.

4 Simulation

Over time, simulation has become a helpful tool in order to study the different problems related with constraints and tails theory, helping us analyze problems in real-time series, by assuring the identification of possible problems, for them to be submitted.

The simulation is interpreted as the imitation of a moving object, ie a system. From its continuous research, multiple authors personify its definition according to its application in different fields:

— Representation of a system operated by a simulator, subject to manipulations, that if used in the real system, would be expensive or impractical, in order to know its operating properties (Shubik, 1960).

- Numerical or graphical description of the time trajectory of the variables involved in the development of the system using a digital or analog computer (Kalman, 1960).
- Tool that manages experiments in a PC, which requires logical and mathematical models that describe the behavior of a system in assumptions of real time (Naylor, 1969).
- The objective of generating a simulation is to understand its behavior, so that possible strategies can be evaluated to achieve its control and operation (Shannon, 1988).

It is possible to conclude that the simulation is an instrument that, through a PC, approximates to imitate the dynamics of a real model interpreted with logic, mathematics and complexity, having as object the knowledge of its reaction to deliberate events to improve the quality of the decision.

4.1 Buliding The Model

As mentioned in the introduction, the simulation of the production process of the ”Industrial C25 industrial glove” was scheduled for an 8-hour work shift, starting at 6 a.m. and ending at 2 pm.

This model was simulated in the Pro-Model Software version 8.6. The construction was undoubtedly complex, since in the immersion operation, the system worked in parallel with 6 latex tanks and 6 hydraulic arms that immersed the molds (24 Units) in the mixtures, respecting the sequencing of the sub-process.

To design the simulation model, the following constructors were used:

4.1.1 Layout

In this model, the floor plan was designed on a scale of 1: 100.

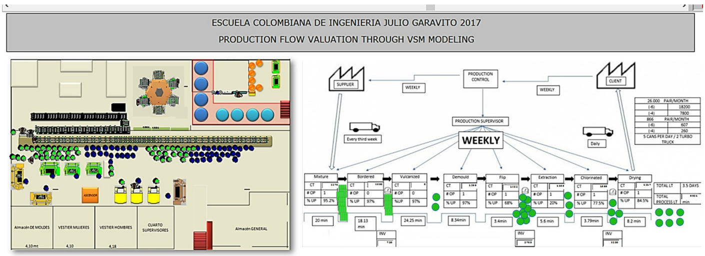

Figure 4: Layout Simulation

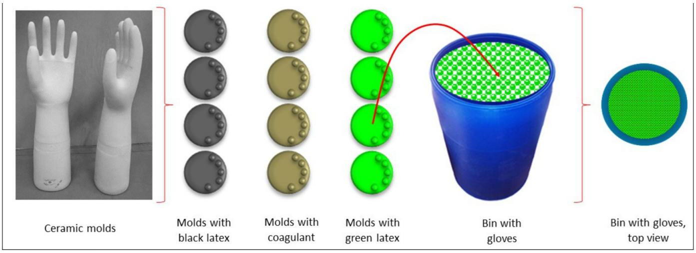

Figure 5: Model Entities

4.1.2 Locations

Those spaces in which there is a transformation or where the product is stored during the process (Entities) . This information, with its respective times, transports and delays was standardized in a flow diagram.

4.1.3 Entities

These are the elements that move within the model. The simulation used different representations to describe the work in process, all these are in top view:

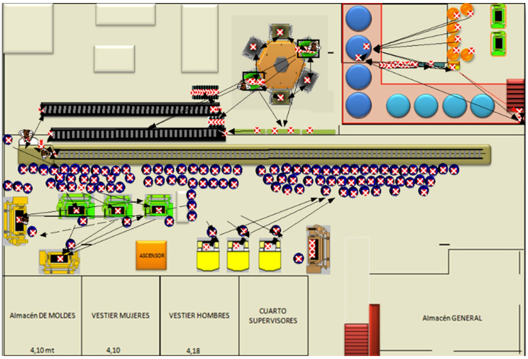

Figure 6: Process Configuration

4.1.4 Processing

This part of the simulation defines the routing of entities through the system and the operations that take place at each location they enter. Each operator has its process above its path network.

4.1.5 Arrivals

An arrival record is defined by specifying the following information: Number of entities, Frequency, time of the first arrival and total occurrences of the arrival. 3 arrivals were worked on for this model; the first arrival of material corresponds to the preparation of the mixture, in which the operator weighs and prepares the mixture in the tanks feeding the immersion system. Considering the proportion of latex consuming the molds in the system, the second material inlet, which is recorded in the immersion system, according to the way the immersion times were set up. Finally, a third material entrance is evident in the de-mold of the glove, next to the vulcanizing furnace, since the de-molded gloves are placed in blue bins, around 576 gloves.

Processing

		Process			Routing	
Entity	Location	Operation	Blk	Output	Destination	Rule
Bombeo	Bascula		1	Bombeo	Mangeras	FIRST 1
Bombeo	Mangeras	wait 0.5	1	Bombeo	Llaves_de_apertura	FIRST 1
Bombeo	Llaves_de_apertura		1	Bombeo	EXIT	FIRST 1
MPGN_0034	Materiales		1	MPGN_0034	Bascula	FIRST 1
MPGN_0034	Bascula	wait 0.4	1	MPGN_0034	Tanque_14	FIRST 1
Bombeo_2	Bascula		1	Bombeo_2	Llaves_de_apertura	FIRST 1
Bombeo_2	Llaves_de_apertura	wait 2	1	Bombeo_2	Agitadores	FIRST 1
Bombeo_2	Agitadores	wait 0.4	1	Bombeo_2	Tanque_14	FIRST 1
Bombeo_3	Bascula		1	Bombeo_3	Llaves_de_apertura	FIRST 1
Bombeo_3	Llaves_de_apertura	wait 1	1	Bombeo_3	Mangeras	FIRST 1
Bombeo_3	Mangeras		1	Bombeo_3	EXIT	FIRST 1
Bombeo_4	Bascula		1	Bombeo_4	Agitadores	FIRST 1
Bombeo_4	Agitadores	wait 0.6	1	Bombeo_4	Tanque_14	FIRST 1
MPGS_0010	Materiales		1	MPGS_0010	Bascula	FIRST 1
MPGS_0010	Bascula	wait 0.4	1	MPGS_0010	Tanque_14	FIRST 1
MPGS_0012	Materiales		1	MPGS_0012	Bascula	FIRST 1
MPGS_0012	Bascula	wait 0.4	1	MPGS_0012	Tanque_14	FIRST 1
Plastificante	Materiales		1	Plastificante	Preparacion_	FIRST 1
Plastificante	Preparacion_	wait 1	1	Plastificante	Tanque_14	FIRST 1
MPGS_0001	Dispersion_1	wait 0.3	1	MPGS_0001	Tanque_14	FIRST 1
MPGS_0002	Dispersion_2	wait 0.3	1	MPGS_0002	Tanque_14	FIRST 1
MPGS_0004	Disp_3	wait 0.5	1	MPGS_0004	Tanque_14	FIRST 1
MPGS_0005	Disp_4	wait 0.3	1	MPGS_0005	Tanque_14	FIRST 1
MPGS_0003	Materiales		1	MPGS_0003	Bascula	FIRST 1
MPGS_0003	Bascula	wait 0.3	1	MPGS_0003	Tanque_14	FIRST 1
MPGS_0003	Materiales		1	MPGS_0003	Bascula	FIRST 1
MPGS_0003	Bascula	wait 0.2	1	MPGS_0003	Tanque_14	FIRST 1
MPGS_0133	Materiales		1	MPGS_0133	Bascula	FIRST 1

Figure 7: Process Algorithm

5 Acknowledgements for the Future Mapping

To transform the current process into a LEAN-type flow by eliminating or reducing waste, the research group met with management to explore the feasibility of a change in purpose of outlining the future map. Regarding the current map, with the help of the simulation, the following improvement points were found:

- A critical bottleneck is evidenced in the Extraction operation (Attended around 3 cups per hour, however, the cups arrive at a rate of 8 per hour)
- There is permanent inventory between operations with a very high WIP (7158 units/day)
- No transport or systemic manipulation.
- The supply of the material is not balanced with the demand.

After this meeting with the managers, it was possible to work with those directly involved, in order to sketch a future map considering the characteristics of a lean chain, such as:

- Produce according to the rhythm of demand (Takt time)
- The construction of a continuous flow.

- Identification of the block within the process
- Perform a balance of loads on the line

6 Lean Thinking

6.1 Takt time

By understanding the Takt time as the rate at which customers consume the product, and considering the information and calculations performed to assemble the current VSM (Hines and Rich, 1997), it is possible to plot the Takt time cycle graph. This graph shows the individual cycles of the operations versus the Takt time of the total system. There is an established demand of 0.36 hours/48 gloves. This operation can be considered a bottleneck, however the company programs more resources without having the immediate need to do so. A balancing and reprogramming line of the work shifts of both the operators and teams is evident. The speed at which all resources are working is less than the Takt speed, which indicates that the efficiencies gained in the process are being lost in the finished product inventory. When the demand does not pull, the company lowers prices to lower the inventory level, but the saved cost is wasted.

6.2 Little Law

Thanks to the VSM, since the first option already proceeds to analyze the yield of the finished chain or of the process that was analyzed previously.

This yield is given by John Little's law, basing on the tails theory since our main problem identified in the VSM is related to the work in process (WIP), cycle time (CT) and throughput (TH)(Hopp and Spearman, 1996), the relation of the 3 variables allow us to identify the problems in the system, as follows:

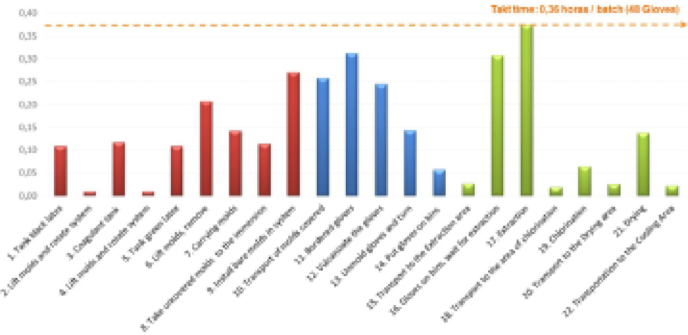

Figure 8: Balance workloads

6.2.1 Cycle Time (CT)

Proceeds according to the time that takes every operation in extracting the batch defined previously:

$$\begin{aligned} CT_{total} = CT_{OP1} + CT_{OP2} + CT_{OP3} + CT_{OP4} \\ + CT_{OP5} + CT_{OP6} + CT_{OP7} + CT_{OP8} \end{aligned} \quad (1)$$

$$CT_{TOTAL} = 120,9\, minutes \quad (2)$$

6.2.2 Work in Process (WIP)

Proceeds as follows, bearing in mind the inventories that were appearing between processes

$$WIP_{total} = WIP_{OP1\quad OP2} + WIP_{OP2\quad OP3} + WIP_{OP3\quad OP4} \\ + WIP_{OP4\quad OP5} + WIP_{OP5\quad OP6} + WIP_{OP6\quad OP7} + WIP_{OP7\quad OP8} \quad (3)$$

$$WIP_{TOTAL} = 7158\, units \tag{4}$$

6.2.3 Throughput

Having calculated our CT and entire WIP, with the following relation we can look at the following yields (Jirsák and Holman, 2012):

Yield of the process

This yield is given by the relation of the cycle time found in the whole process and the WIP of the same:

$$TH = \frac{WIP}{CT} = 98,08\, \frac{units}{minute} \tag{5}$$

Yield of the chain

To find the yield of the finished chain, the Cycle Time was calculated from the arrival of raw material up to delivery to the different clients, taking as the same for all, likewise our WIP is the same that of the previous process:

$$TH_{CHAIN} = \frac{WIP_{PROCESS}}{CT_{CHAIN}} = 2,35\, \frac{units}{minute} \tag{6}$$

In conclusion, according to the calculations, it was found that the value given by the TH is relatively high regarding the cost for the processed inventory.

In order to diminish this value and for the cost yield to be ideal, it is proven that the option to locally apply the LEAN tool, 5S Kaizen. To improve the yield, it might implement a line swinging, bearing in mind the whole finished chain and so, to unify the whole process from the requisition of raw material up to the delivery of the product to the final client (Blank, 2013).

operation	immersion	bordered	vulcanized	demould	flip	extract	chlorinated	drying		
machine time	21	18,7	25	8,6	5	28	4,9	9,7	120,9	minutes
takt time	0,006045	minutes/pair								

Figure 9: Calculation of Takt Time

6.3 CONWIP

As the second measurement, WIP is found that allows us to minimize the incurred costs (Blanco, Motta, 2006), for it we proceed to find our inventory in the process allowed by the line, as follows:

Calculating the takt time, allow us to identify the frequency and the rhythm of the process, therefore, it proceeds to be compared with the time that it takes each operations to produce the batch defined in the VSM, this allows us to identify the specific bottleneck of the process:

$$takt\,time = \frac{time\;avalaible\;per\;operation}{demand\;of\;de\;chain} \tag{7}$$

$$takt\,time = 0.006045\,\frac{minutes}{pair} \tag{8}$$

Having identified the bottleneck, its valuation proceeds with the following equation:

$$r_b = 1,71\,\frac{units}{min} \tag{9}$$

Knowing our raw process time:

$$T_0 = 91,73\,minutes \tag{10}$$

We proceed as with the first measurement to calculate the critical WIP:

$$W_0 = r_b * T_0 W_0 = 157,25\,units \tag{11}$$

(12)

Finally, the CONWIP is:

$$CONWIP = 160\,units \tag{12}$$

It is possible to infer, with the calculations, that the inventory in an ideal process is of 160 units, this in relation to the inventory in the current process (7158 units), it shows that it is necessary to reconsider the distribution of the process, defining so, minimal distances to be covered, minimal dead times, with the studied CONWIP.

On the other hand, considering the balance of the process flow against the takt time, it is evident that the demand (2.78 Batch/hour) of this product is much lower than the supply. Although the appearances of the process show the opposite, in the sense the bottleneck determines the speed of supply (2.68 batch/hour). The analysis shows that the bottleneck is aligned with demand, something appropriate, however, the other operations have a much higher speed than the restriction, which means that these resources are being programmed without meaning. If in the future map, the speed of all the operations is aligned to the takt time, that is to say, to the bottleneck, a saving of 0.40 Batch/hour in the process would be achieved.

7 Improvements

The purpose of the VSM methodology is based on the diagramming of the current situation of the process in order to understand the dynamics, needs and spaces for improvement. After this balance, points are identified to modify or deepen their research, to be developed the future VSM so that waste is reduced and the flow increases responding more effectively, lower cost and added value recognized by the customer.

In the present case the current VSM was diagrammed through the simulation in Promodel, able to identify the following improvements to design the future VSM:

1. It was possible to identify the bottleneck of the system with the simple observation of the model. With a proper line balancing synchronized with the operations shifts of the operations will achieve a continuous flow with a much greater throughput (Process speed), reducing operating costs.

2. Throughout the process was a high level of inventory in process, a result of the bottleneck and regular planning for the market. This opportunity for improvement was exploited through three practices:

   — By measuring takt time, the speed of the process will be matched to market demand, which will be amortized through proper inventory planning.

   — Through plant physics, understanding Little's law will further increase throughput, balancing cycle time and product in process, defining the CONWIP to use in the future VSM.

   — Bearing in mind that the market has been in the last decade emerging with the 15 references that the company produces, for the future VSM will be realized the planning through the Heinjunka philosophy, that is, to level the variety and quantity of the products with the market Creating a continuous flow with an initial pull.

8 Relevance for the Sector

Combining lean thinking (VSM) with discrete modeling waste is evident at first glance. Through this visual tool, the management of the organization will observe the behavior of the industrial process against its VSM in detail through a simulator with graphs and real-time indicators of the simulation. The reactions are immediate and the decision making occurs in the short term. With this tool the entrepreneurs of the sector will be aware that waiting to build an action plan will take time. Waste is synonymous with loss of capital, so that industries will evolve their thinking against the instruments of continuous improvement.

In this sense, this application will help close the gap between the role of the university and industry in this sector. Unfortunately, in the domestic industry, the thought of an application technology unusual for continuous improvement as discrete simulation, it becomes an investment, which is ineffective in the reality of its operation (Eslava, 2017) (Sánchez, 2015).

9 Conclusions

By using the VSM, it was possible to identify the different operations that do not add value to the process, in this way diagnosing the different progress options that could occur by applying the LEAN tool, focused locally in the operations.

The application of this tools locally allows us to fit the times of every process, in order to minimize the incurred cost for inventory in process or in dead times regarding personnel.

When using the VSM tool with the help of the PROMODEL software, it is observed that thanks to this tool combination real-time information is obtained in relation with prosecution times of the raw material, inventories simulated at the date of the situation, waste generated in each of the operations and analysis of the efficiency and yield of the system.

This helps us to control and improve the economic impacts that could be generated by changes in production planning, changes in distribution times and reception of materials, helping minimize the variability to generate different restrictions of the system.

References

Abdulmalek, F. A. and J. Rajgopal (2007). "Analyzing the benefits of lean manufacturing and value stream mapping via simulation: A process sector case study". In: *International Journal of Production Economics* 107.1, pp. 223–236.

Blank, S. (2013). *Why the lean start-up changes everything*.

Calva, R. C. C. (2014). *TPS Americanizado: Manual de Manufactura Esbelta*. Rafael Carlos Cabrera Calva.

Ernesto, B. R. L. (2001). *Simulación con Promodel, Casos de Producción y Logística*. 2nd ed. Escuela Colombiana de Ingeniería Julio Garavito.

Harrel Gosh, B. (2000). *Simulation using Promodel*. McGraw Hill.

Hines, P. and N. Rich (1997). "The seven value stream mapping tools". In: *International Journal of Operations & Production Management* 17.1, pp. 46–64.

Hopp, W. and M. Spearman (1996). *Basic Factory Dynamics*.

Jirsák, P. and D. Holman (2012). "Productivity of Lean Logistics System". In: *Journal of Logistics & Sustainable Transport* 13.1, pp. 30–40.

Jones, D. T., P. Hines, and N. Rich (2001). "Lean Logistics". In: *International Journal of Physical Distribution & Logistics Management* 27.3/4, pp. 153–173.

Lasa, I. S., C. O. Laburu, and R. D. C. Vila (2008). "An evaluation of the value stream mapping tool". In: *Business Process Management Journal* 14.1, pp. 39–52.

Lovelle, J. (2001). *Mapping the value stream*.
Luis Ernesto Blanco Rivero Enrique Romero Motta, J. A. P. R. (2006). “CONWIP UN SISTEMA DE CONTROL DE PRODUCCIÓN”. In: *Fourth LACCEI International Latin American and Caribbean Conference for Engineering and Technology (LACCET 2006)*, p. 7.
Muhammad al-Ashraf, R. A. R. (2012). “Production Flow Analysis through Value Stream Mapping: A Lean Manufacturing Process Case Study”. In: *ElSevier*, pp. 1727–1734.
Wu, Y.-C. J. (2002). “Effective Lean Logistics Strategy for the Auto Industry”. In: *The International Journal of Logistics Management* 13.2, pp. 19–38.