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Applying value stream mapping for design and optimization of a chocolate bar production line

Aplicación de value stream mapping para el diseño y optimización de una línea de producción de barras de chocolate

GUTIÉRREZ-SÁNCHEZ, Vicente Alberto†* & GUILLÉN-GUZMÁN, José Fernando

Postgraduate CIATEQ, A.C., Tabasco, Mexico.

ID 1st Author: *Vicente Alberto, Gutiérrez-Sánchez* / **ORC ID:** 0000-0003-1168-3129

ID 1st Co-author: *José Fernando, Guillén-Guzmán* / **ORC ID:** 0000-0002-5353-8838

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Abstract

Objectives. The objective of this paper is to present the contribution of Value Stream Mapping (VSM) to design and optimization of a chocolate production line. Methodology. Initially data was collected for VSM parameters, within a four-month period for the design of the Current State Map. Future State Map was developed by equalizing production volumes to the line product's Takt Time. A model implementation was carried out and efficacy was evaluated. Contribution. VSM allowed the company to increase uptime of the cooling process by 31.7% and 85g bar overproduction reduction by almost 100%. The company has found this tool highly useful for diagnostic analysis of production. However, the implementation of continuous improvement tools and infrastructure betterment will be needed to achieve higher efficiency.

VSM, Optimization, Chocolate

Resumen

Objetivos. El objetivo de este artículo es presentar la contribución del Mapeo de Flujos de Valor (VSM) al diseño y optimización de una línea de producción de chocolates. Metodología. Inicialmente se recolectaron datos de los parámetros VSM, en un período de cuatro meses para el diseño del Mapa de Estado Actual. El Mapa de Estado Futuro fue desarrollado al igualar los volúmenes de producción al Takt Time de los productos de la línea. Se llevó a cabo la implementación del modelo y se evaluó la eficacia de éste. Contribución. El VSM permitió a la compañía incrementar el tiempo de (uptime) del proceso de enfriado en un 31.7% y reducir la sobreproducción de barras de 85g casi al 100%. La compañía encontró altamente útil esta herramienta para el diagnóstico y análisis. Sin embargo, la implementación de herramientas de mejora continua y el perfeccionamiento de la infraestructura serán necesarios para lograr mayor eficiencia.

VSM, Optimización, Chocolate

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* Correspondence to Author (E-mail: vicente@cacep.com)

† Researcher contributing first author.

Introduction

Value Stream Mapping (hereafter VSM) is a visual tool for measuring and analyzing a production flow that contributes to continuous improvement. A visual map of the production is drawn, and indicators are placed throughout the chain, at each phase (Martin & Osterling, 2014). Recent years have seen the popularity of lean management implementation increase, while VSM has proven particularly helpful in different domains, from supply chains related to food production and waste (De Steur et al., 2016) to oil and gas chain processes (Vasconcelos Ferreira Lobo et al., 2020). It has even branched out from manufacturing domains and entered into the service industry (Setiawan et al., 2022).

The last decade has seen different studies zoom in on the contributions of VSM to increase productivity. For example, in Product Development, VSM enables collective analysis and overcomes compartmentalized thinking, which is an essential feature for product development (Maryl et al., 2013). In addition, Schulze et al. (2013) also link VSM to organizational learning processes.

Despite VSM's potential contributions to the production of chocolate bars, this is a topic that has gone underexplored. Only very recently have some studies explicitly stated the usefulness of VSM for chocolate-based products (CBP) manufacturing. For example, Calderon (2017) found efficiency improvements after applying VSM, along with other lean manufacturing tools, for CBP production at Cal Poly (a student union in the California Polytechnique State University). In turn, Sibanda and Ramanathan (2018) performed an integrative approach to discover how quality control allowed reduction in the variation of CBP manufacturing process in a UK company. Although numerous tools were involved in their study, the Value Stream Map was part of the Measurement phase. More recently, Bertagnolli (2022) used the example of CBP manufacturing to illustrate how VSM could be helpful in such processes. However, despite being a valuable example, it only served illustrative purposes and details of analysis were not presented.

This research aims to present the usefulness of lean management implementation techniques to the manufacturing process of chocolate products. A case study of a Mexican company: Grupo Industrial Cacep S.A. de C.V. (GICSA). GICSA is an agribusiness company, based at Comalcalco, Tabasco, Mexico. This company is dedicated to production and sales of cacao and chocolate products, being its commercial brand "Cacep Chocolates". The company offers more than 200 products, being 85g chocolate bars some of the most representative products of the organization. Because the company forecasts that the supply will be insufficient by 2022, it decided to acquire an automatic chocolate bar production line.

The next section offers a literature review on VSM and outlines its relevance for chocolate manufacturing processes. Then, the methodological approach is described. The results are presented afterwards. Finally, the conclusion offers a discussion on the contributions of VSM to chocolate bars manufacturing.

Literature Review

Value Stream Mapping

Rother and Shook (2003) describe VSM as the tool that tracks the production path of a product from the customer to the supplier, creating a visual representation of each production step, aimed to design the process in order to fulfill the demand expectations. The authors mention that this is a "states" tool, in which a current state or scenario is proposed, and a VSM map of future states is elaborated, on how the process should be optimally.

In the elaboration of a standard VSM map, there is an assumption that a philosophy of continuous improvement has been adopted, such as Kaizen (Martin & Osterling, 2014). In addition, VSM relies on another tool called the Product-Process Matrix, which helps to identify in a timely manner the processes or threads of a given product. At the same time, it allows visualizing the similarities and differences between the processes of each product. With it, the creation of the "Current Status" map of the process of interest is facilitated.

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The next step after applying the Product-Process Matrix to flowchart a process (Réquillard, 2020), is to perform the first mapping process. In this case, you can choose to map the entire value chain of the organization or a specific process line. It is advisable, for starters, the exercise of a specific production line. This yields the “Current Status” map.

The "Current Status" map is a diagnostic tool, where the work team can identify any failure or inefficiency of the analyzed process. VSM will be applied to identify improvement opportunities. According to ASQ, one of the tools for this is the implementation of a second VSM map, which is known as a "Future State Map" (FSM). The "Future State Map" represents a visual objective, which answers the question: *What do I want to improve?* This defines the desirable improvements, seeking the prevention of waste or “muda” from Lean Manufacture (Womack & Jones, 2003) and increased production efficiency. Having a clear image of the process we want to achieve, then it will be easier to implement focused improvement strategies (Noto & Cosenz, 2021).

Processes in GICSA

The company launched a project for the acquisition and installation of the automatic chocolate bar production line, mainly focused on 85g bars, with which manual and semi-automatic processes can be substituted, including tempering, molding and cooling (solidification), described in the following section:

1. Tempering. It consists on manipulating liquid chocolate temperature to alter the structure of molecular bonds, focusing on obtaining better shine, texture and uniformity for the final product (85g chocolate bars). Geoff Talbot describes it as the conversion of liquid chocolate into a partially *crystallized* state, adequate for its later use on the molding process. (Talbot, 2009) The tempering “curves” vary depending on the volume and type of chocolate. An example of a tempering curve could be the following: 45°C -> 28.5°C ->29.5°C. A three-state temperature curve is commonly used, being the first state 45°C, the second 28.5°C and finally 29.5°C considering the previous example. Tempering is critical for chocolate molding, as a correct processing will provide a high-quality chocolate bar (Id. ibid).

2. Molding / Depositing. The following process from tempering is depositing or molding. When the third temperature state is achieved, liquid chocolate is deposited into molds that, for this case, count with three 85g cavities each. In this way, liquid chocolate will take the form of the cavity (Minifie, 1999; Talbot, 2009).

3. Cooling. Once the chocolate is inside the mold, chocolate must be cooled, reducing the molded chocolate temperature within ranges from 3°C to 10°C. With this, chocolate starts to solidify, effectively producing chocolate bars. After this comes a demolding step, extracting solid chocolate from the cavities (Id. ibid).

These three processes make up the automatic CBP production line, owned by GICSA, acquired in 2021. As a reference, a picture of the process is shown:

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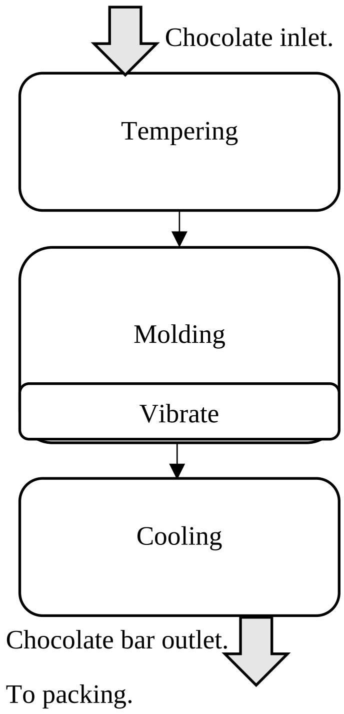

Figure 1 Example of production flow stream for 85g chocolate bars
Source: Author's contribution (May 2022)

The line is formed by three main modules: Temperer (1), Molder (2) and Cooler (3), which perform the functions previously mentioned. Modules interconnect to generate a continuous production stream. In theory, the line should work according to productivity parameters indicated by the manufacturer. Nevertheless, it does not reach the desired productivity specifications. For this reason, the decision of analyzing the value stream was taken, through the use of Value Stream Mapping.

Methodological approach

The methodology used on VSM implementation in GICSA for its automatic chocolate bar production line consisted of four main phases: **measurement, diagnosis, analysis and improvement**. In general, first three phases' results will be presented in the results section, while improvement will come to line integrated as a part of the discussion section.

Measurement: Data was collected throughout four months, stored in an Excel document, focusing on production rates and line occupancy (time data). Information was captured daily by line operators and reviewed by the production manager.

The strategy consisted on measuring parameters during two weeks, using personnel observers (2) to the line. Material was provided to do this, such as chronometers, log notebooks (and pens) and a computer with a data processing software. In the next list, parameter obtention or calculation will be explained:

- Personnel was provided with chronometers to measure time. **Processing time, cycle time and setup time** (see diagnosis phase) were tracked using this. All information was registered manually and electronically. At the end, times were averaged for a single day. Time error was less than 1% for processing time and cycle time; while setup time, the median was taken, as time error was high because of irregular personnel availability to setup the machine. All of this was measured individually for each line module.

  - Cycle time for the cooler had issues, as the machine was not fully loaded. Empty spaces were left due to mold processing (3 bars) as the cooler is faster than the latter, causing it to double Cycle time (14.8s instead of ≈ 7.4s per bar). Max. capacity is based on 7.4s per bar.

- Uptime was calculated using **Equation 7.** According to the previous parameters and daily production rates, for the molderer and the cooler. The temperer method was using the chronometers, as its working time depends on the other two modules.

Diagnosis: Once data was collected, a Current State Map (CSM) was created to visually analyze the flow stream using previous data. (*Value Stream Mapping Tutorial - What Is VSM? | ASQ*, n.d.) For this phase, first VSM parameters were defined, applied to every of the before-mentioned processes, considering mainly the following:

- Takt Time.

- Production rates.

- Operator count.

- Processing Time.

- Cycle Time.

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- % Uptime.
- Setup Time.
- #Shifts.
- Maximum Available Time (amount and percentage for the last).

Other valuable weighted parameters are the following:

- Delivery times for information, raw materials and client deliveries.
- Waiting times.
- Lead Time.
- General processing time.
- General %Uptime.

The use of equations was fundamental during this section. Parameters are related to each other, and in many cases modification of one parameter may affect the other. Main equations are therefore presented and described as follows:

- Equation 1.

$$Daily\ Bar\ Demand = \frac{TotalDemand}{TotalWorkingDays} \quad (1)$$

Where *Daily Bar Demand* is the number of bars that should be produced to comply with the demand; *Total Demand* is the accumulated sold chocolate units within a defined period; and *Total Working Days* is the number of days that the company worked.

- Equation 2.

$$Takt\ Time = \frac{TTWD_{min}}{DBD} \quad (2)$$

Where *Takt Time* is a VSM parameter value used to define de amount of time **desired** to produce a unit of product (a bar in this case); $TTWD_{min}$ is the total effective time of a working day in minutes, i.e., 480 min for this case; and "DBD" *Daily Bar Demand* is the number of bars that should be produced to comply with the demand.

- Equation 3.

$$TBP = \sum_{1st\ Jan\ 2022}^{30\ April\ 2022} DCPD \quad (3)$$

Where TBP is "Total Bar Production" and *DCPD* is "Daily Collected Production Data". This Equation is used to indicate the summation of daily collected values of chocolate bars production within the period starting from January 1st to April 30th.

- Equation 4.

$$DBP = \frac{TotalBarProduction}{TotalWorkingDays} \quad (4)$$

Where "*DBP" Daily Bar Production* is the average production rate at which the line works for a given period; Total *Bar Production* is the accumulated amount of chocolate bars produced in a given period; and *Total Working Days* is the number of days that the company actually worked.

- Equation 5.

$$ProductionRate = \frac{TTWD_{min}}{DBP} \quad (5)$$

Where *Production Rate* is a VSM parameter value used to define the real time **taken** to produce a unit of product (a bar in this case); $TTWD_{min}$ is the total effective time of a working day in minutes, i.e., 480min for this case; and *"DBP" Daily Bar Demand* is the number of bars that should be produced to comply with the demand.

- Equation 6.

$$\%TPC = \frac{DBD}{MIC}\ or\ \frac{DBP}{MIC} \quad (6)$$

Where %*Total Production Capacity* is the percentage of line production usage, obtained by dividing the production daily or daily demand over the *Max Ideal Capacity "MIC"; Max Ideal Capacity* is the maximum real achieved production in a day; refer to Equations 1 and 4 to see the definition of *Daily Bar Demand "DBD" and Daily Bar Production "DBP".*

- Equation 7.

$$\%\ Uptime_M = \frac{CT\ x\ DBP}{TTWD_s} \quad (7)$$

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Where *%Uptime* is the time that the machine is working and producing units, subindex “M” indicates that is applied to the **molding** process; “CT” *Cycle Time* is the VSM parameter that defines the time taken between each inlet/outlet of product; for *Daily Bar Production* “DBP”, refer to **Equation 4**; and $TTWD_s$ is the total effective time of a working day in seconds, i.e., 28,800 seconds for this case.

- Equation 8.

$$\%Uptime_C = \frac{PT\ x\ n_{batches} + CT\ x\ DBP}{TTWD_s} \qquad (8)$$

Where *%Uptime* is the time that the machine is working and producing, subindex “C” indicates that is applied to the **cooling** process; “*PT*” *ProcessingTime* is the VSM parameter that measures the time a product lasts within a process, from beginning to end; “*CT” Cycle Time* is the VSM parameter that defines the time taken between each inlet/outlet of product; for *Daily Bar Production “DBP”,* refer to **Equation 4**; $TTWD_s$ is the total effective time of a working day in seconds, i.e., 28,800 seconds for this case; and $n_{batches}$ is the number of batches that will take place during a selected period of time (see **Equation 12**).

- Equation 9.

$$Max.A.T.A. = TTWD_s - Downtime \qquad (9)$$

Where $TTWD_s$ is the total effective time of a working day in seconds, i.e., 28,800 seconds for this case; *Downtime* is the sum of the parameter *SetupTime*, and time taken to clean and perform maintenance to the machine, refer to **Equation 10**.

- Equation 10.

$$Downtime = ST + Clean + MT \qquad (10)$$

Where *SetupTime* is the VSM parameter that measures the time needed to setup the machine so it can start working; “*Clean” CleaningTime* is the average time taken to clean a certain machine; *MT* is the average time taken to perform any kind of maintenance to a certain machine.

- Equation 11.

$$\%Max.A.T.A. = \frac{Max.A.T.A}{TTWD_s} \qquad (11)$$

Where $TTWD_s$ is the total effective time of a working day in seconds, i.e., 28,800 seconds for this case; for *Max.A.T.A* check **Equation 9.**

- Equation 12.

$$n_{batches} = \frac{DBP}{BarsPerBatch}\ or\ \frac{DBD}{BarsPerBatch} \qquad (12)$$

Where $n_{batches}$ is the number of batches that will take place during a selected period of time, it has to be stated that this is an integer number, therefore a roundup should be done if decimals are present; *BarsPerBatch* is the characteristic installed capacity of a machine per batch, accounts for the number of bars that can be processed at a same time; for the other two parameters see **Equations 1 and 4**.

- Equation 13.

$$LeadTime = \sum PT_n + \sum NVAT \qquad (13)$$

Where Lead Time is the total time taken since a customer place an order until it reaches the customer; “PT_n” *ProcessingTimes* considers the sum of every *“PT”* from all modules; *“NVAT” NonValueAddedTimes* consider delivery times for information, raw materials and client deliveries, but also waiting product time (such as inventory stall time) and setup time.

With the previous values, the construction of the Current State Map may be achieved. Before getting into the analysis phase, possible improvements are detected. This consists on knowing the relation between practical improvements and their impact on the parameters. Having this knowledge allows the researchers to identify possible Kaizen events, placed visually in the Map, by adding “star-like” yellow indicators that mention the feasible solutions (George, 2005).

Once the indicators are placed, a solution should be selected for each tag. Each solution may impact on a parameter value; therefore, estimations will be made for each parameter. Some are calculated to achieve desired objectives. These last parameters are obtained in the analysis phase. This will be shown in further sections.

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Analysis: This phase helps with the calculation of the main parameters mentioned in the diagnosis phase, yet these will be modified to calculate Future State values. The following steps were taken:

1. First, *Takt Time of the Demand* should be equal to *Production Rate*. This was done by letting *Production Rate* to have the value of the first.

2. Second, we have to obtain *Daily Bar Production* by clearing out the Equation, using the newly formed *Production Rate.*

3. Then, before calculating %Uptime, it has to be checked if *Processing Time* or *Cycle Times* have changed. These values are characteristic to the machines. If an improvement was made, a value may have changed, so it has to be measured again with a chronometer.

4. After that, having updated *PT* and *CT* values for all the modules, the first %Uptime to calculate is the $\%Uptime_M$ (molderer), as we have all the parameters to obtain it. Use **Equation 7** for this.

5. Then, for the $\%Uptime_C$ first the $n_{batches}$ must be obtained. Check the number of bars that can be processed in one batch, and calculate based on the adjusted *Daily Bar Production* using **Equation 12**.

6. $\%Uptime_C$ can now be calculated by using **Equation 8,** as we have all parameters.

7. To obtain $\%Uptime_T$ (temperer), chronometer method is used. Time elapsed between the start of the actual process (setup not considered) and the end of it.

8. The rest of the values mentioned in the diagnosis phase, should be placed as objectives. Estimations can be made, though must be achievable. These have to be supported on Kaizen events and improvement proposals, and congruent relations between parameter-improvement must exist. Also setting goals too optimistic, may incur into a faulty Future State Map.

9. Finally, total Processing Times and Lead Time must be calculated. Processing Times is obtained by summing up the contributions of all modules PTs; while Lead Time is calculated by using **Equation 13.**

Having all the values obtained, we can proceed to build the Future State Map, which will serve as a guide to the next phase.

Improvement: In this part, real improvements are implemented. Tracing improvements is ordinarily done through digital logs, decision tables and relational tables (in this case was done in Excel). Each improvement is related to one or multiple Kaizen Events, and can also be related to one or multiple parameters. As seen in the analysis part, Equations are connected to each other.

Some of the mentioned proposals for this research, are the following:

- Load Leveling. This is an administration and production tool that balances the production flow through a process. Prevents production “spikes” from appearing. (*Value Stream Mapping Tutorial - What Is VSM? | ASQ*, n.d.)

- SMED. “Single Minute Exchange of Die”, methodological Lean tool that allows to reduce setup and changeover times. (Réquillard, 2020)

- JIT. “Just in time”, a method to improve production flow. Its core is that everything has to be “Just in time”, no inventories nor delays. (Id. ibid)

- TPM. “Total Productive Maintenance”, a Kaizen tool to trace maintenance issues, and is considered as a “fail-proof” method. (George, 2005)

- Infrastructure improvement. Means that investment on infrastructure should be done, specifically to improve environmental conditions.

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- Kaizen. This is one of the core elements of *Lean Thinking.* Translating it from Japanese, it means "continuous improvement". It applies to different scopes such as production, quality, processes or even daily life. (Imai, 2014) For this research, Kaizen will be mainly applied to human resource constant development.

Finally, as enhancements are done, it has to be revised if the proposed solution actually generates an improvement. The results obtained through the defined methodology in this section, will be discussed in the next sections.

Results

Current State Map Results

Prior to the results of measurement phase, a major technical issue was found for the molding module (molderer). This phase did not work as expected, causing the company to stall the machine and deciding to substitute the process with manual molding. It is important to point out to the reader that the following molding data is for a manual molding process. Whenever the term **"molderer"** is used, it is referencing the manual process.

In this section, summarized average collected data will be presented, followed by data processing and construction of VSM maps. Collected data was taken considering the tempering, manual molding and cooling subprocesses that conform the production line, and resulted as follows:

85g bar Chocolate Demand - 4 Months - Jan/April 2022			
Total 85 g Chocolate Bar Demand (Pieces)	Total Working Days (days)	Daily bar demand (Pieces/Day)	Max ideal Capacity (Pieces/Day)
24422	103	237.10	3003.90
Total time by Working Day (hours)	Total time by Working Day (minutes)	Daily Takt Time (min/bar)	% Total Production Capacity
8	480	2.024	7.89%

Table 1 Chocolate demand of 85g chocolate bars from January 2022 to April 2022
Source: Author's contribution (May 2022)

A brief explanation is provided for Chocolate demand table:

1. Total 85g chocolate bar production accounts for the whole number of bars sold during the period.

2. Total Working Time considers the number of days that the production line actually worked. In this case, the value is 103 days, from January to April 2022, subtracting Sundays and holidays.

3. Daily bar demand is the average chocolate demand that should be produced during working days to comply with customer demand. This was calculated by using **Equation 1**.

4. Total time by Working Day (hours) is the number of hours that account for an entire daily shift.

5. Total time by Working Day (minutes) is the number of minutes that account for an entire daily shift.

6. Daily takt time measures the ideal time rate at which each bar should be produced, calculated on a 480min basis. Takt time was obtained by using **Equation 2.**

7. Max ideal capacity is the maximum number of bars that the organization achieved, working the machine at full throttle, continuously, not considering quality controls.

8. %Total production capacity indicates the ideal percentage of production line occupancy to achieve the customer demand. Calculated with **Equation 6**.

Collected information for Total demand and Total working time were taken from the main storage control software that is utilized by the main distribution center of GICSA. Takt time calculation was based on the method used by Reda and Dvidevi (2021).

Table 1 refers only to the demand parameters. Following this, come the results for the general data collection that present the actual production values within the given period:

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General Data Collection - 4 Months - Jan/April 2022			
Total 85g chocolate bar production (Pieces)	Total Working Days (days)	Daily bar production (Pieces/Day)	Max ideal capacity (Pieces/Day)
41823.00	103	406.05	3003
Total time by Working Day (hours)	Total time by Working Day (minutes)	Daily production rate (Production Rate) (min/bar)	% Total production capacity
8	480	1.182	13.52%

Table 2 General data collection of the production line from January 2022 to April 2022
Source: Author's contribution (May 2022)

A brief explanation is provided for the General data collection table:

1. Total 85g chocolate bar production accounts for the whole number of bars produced within the period. The result was obtained from using **Equation 3.**

2. Total Working Time considers the number of days that the production line actually worked. In this case, the value is 103 days, from January to April 2022, subtracting Sundays and holidays.

3. Daily bar production is the average chocolate production considering working days only. This was obtained with **Equation 4**.

4. Max ideal capacity is the maximum number of bars that the organization achieved, working the machine at full throttle, continuously, not considering quality controls.

5. Total time by Working Day (hours) is the number of hours that account for an entire daily shift.

6. Total time by Working Day (minutes) is the number of minutes that account for an entire daily shift.

7. Daily production rate (or Production Rate), measures the rate in minutes at which each bar is being produced, calculated on a basis of 480 minutes. **Equation 5** was used to obtain this value.

8. %Total production capacity indicates the ideal percentage of production line occupancy to achieve the customer demand. Calculated with **Equation 6**.

Moving forward, Current State Map parameters were originally taken from the manufacturers, but it was found that the working site were the line is placed, does not comply entirely with the optimal conditions asked by the suppliers. The main difficulty found was that environmental conditions required the following parameters:

Optimal Environmental Parameters	
Relative Humidity (%)	Room Temperature (°C)
50-60%	<25
Real Environmental Parameters	
Relative Humidity (%)	Room Temperature (°C)
50-80%	<28

Table 3 Environmental parameters for the production line
Source: Author's contribution (May 2022)

In this manner, optimal production parameters were not always achieved, causing production delays mostly. Data collection was needed to test real machine effectivity.

As defined in the method section, parameters such as Processing Time, Cycle Time and Setup Time were obtained through chronometer measuring. This allowed to generate the 9 following values:

- Processing time
  - Temperer value
  - Molderer value
  - Cooler value
- Cycle Time
  - Temperer value
  - Molderer value
  - Cooler value
- Setup Time
  - Temperer value
  - Molderer value

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- Cooler value

With these, **%Uptime** for molderer and cooler where calculated, using **Equations 7 and 8** respectively. Following this, Max. Available Time was obtained by combining **Equations 9 and 10.** In the last case, *CleaningTime and MT* for Equation 10 were measured using the chronometer method. Setup Time had already been calculated.

After the initial results were obtained through the given methodology, a Current State Map is presented to summarize the information:

Current State Map Parameters			
Parameters:	Temperer	Molderer	Cooler
Processing Time (s/bar)	1200	8.67	2100
Cycle Time (s/bar)	1.91	8.67	14.8
Setup Time (s)	1800	600	300
Uptime (% of max available time usage)	40%	12%	42%
Shifts (8 hour shifts)	1	1	1
Max. Available Time Achieved (s)	21600	23328	25200
Max. Available Time Achieved (%)	75.00%	81.00%	87.50%

Table 4 Current State VSM Map parameters
Source: Author's contribution (May 2022)

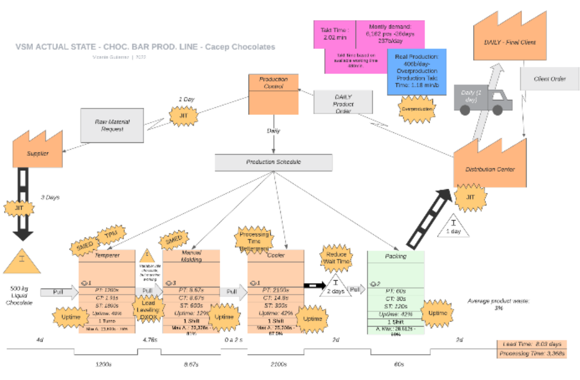

Figure 2 Current State – Value Stream Mapping
Source: Author's contribution (May 2022)

The % of Max. Available Time Achieved is obtained through **Equation 11**.

Extra data was collected in order to build the Actual VSM Map, such as supplying time, delivery time, waiting times, packing processing data, among other information.

Combining the VSM parameters with extra data, the resulting map is built. Actual and Future State maps building was adapted to the needs of the organization, based on Reda and Dvivedi (2021) and Martin and Osterling (2014). Having the Current State map done, the next step is to analyze information in order to generate a more efficient production program. What is important to notice is the placement of Kaizen event markings (yellow signs), which indicate where and what in the value stream should be improved. Enhancements will be shown in the Discussion section.

Future state map results

The second part of the results found concern the Future State Map. In this subsection the parameter values of the FSM will be shown.

In this case, **Table 1 is used to calculate FSM parameters**. As a Load Leveling solution, 20g chocolate bar demand is added, as now two products are being processed for FSM, 85g and 20g bars. The 20g bar demand information is shown in Table 5.

20g bar Chocolate Demand - 4 Months - Jan/April 2022			
Total 20g Chocolate Bar Production (Pieces)	Available time (min)	Daily bar demand (Pieces/Day)	Max ideal Capacity (Pieces/Day)
256933	148319	2494.5120	16895.00
Total time by Working Day (hours)	Total time by Working Day (minutes)	Daily Takt Time (min/bar)	% Total Production Capacity
8	480	0.192	14.76%

Table 5 Chocolate demand of 20g chocolate bars from January 2022 to April 2022
Source: Author's contribution (May 2022)

After 20g demand is obtained, all data is available to calculate the FSM. For this, two parameter tables are obtained using the same method as Current State Map; however, instead of measuring, improvement goals for the parameter values are set. Calculations are based on the restriction that Production Rate must be equal to Takt Time. With this, Daily Bar Production is equal to Daily Bar Demand for both cases, 85g and 20g bars. Then, **equations 7 and 8** are applied to obtain the Uptime values for the molderer and the cooler.

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The rest of the parameters were initially estimated, followed by a measurement using chronometrical methods.

Future State Map Parameters: 85g Bars			
Parameters:	Temperer	Molderer	Cooler
Processing Time (s/bar)	1200	8.67	1800
Cycle Time (s)	1.91	8.67	14.8
Setup Time (s)	1200	300	300
Uptime (% of max available time usage)	67%	7%	24.7%
Shifts (8 hour shifts)	1	1	1
Max. Available Time Achieved (s)	24480	24738	25200
Max. Available Time Achieved (%)	85.00%	85.00%	87.50%

Table 6 VSM Future State Map Parameters for 85g chocolate bars
Source: Author's contribution (May 2022)

Future State Map Parameters: 20g Bars			
Parameters:	Temperer	Molderer	Cooler
Processing Time (s/bar)	1200	1.62	1800
Cycle Time (s)	1.91	1.62	2.77
Setup Time (s)	1200	300	300
Uptime (% of max available time usage)	67%	14%	49%
Shifts (8 hour shifts)	1	1	1
Max. Available Time Achieved (s)	24480	24738	25200
Max. Available Time Achieved (%)	85.00%	85.00%	87.50%

Table 7 VSM Future State Map Parameters for 85g chocolate bars
Source: Author's contribution (May 2022)

Parameters used for Future State Map are equivalent to the corresponding Current State Map, but some values changed and a table for 20g chocolate bars was added. As it can be seen, parameter values highlighted in bold letters are the ones with changes for both 85g bars and 20g bars. With these values, it is possible to create the Future VSM (H. Reda & A. Dvivedi, 2021; Martin & Osterling, 2014).

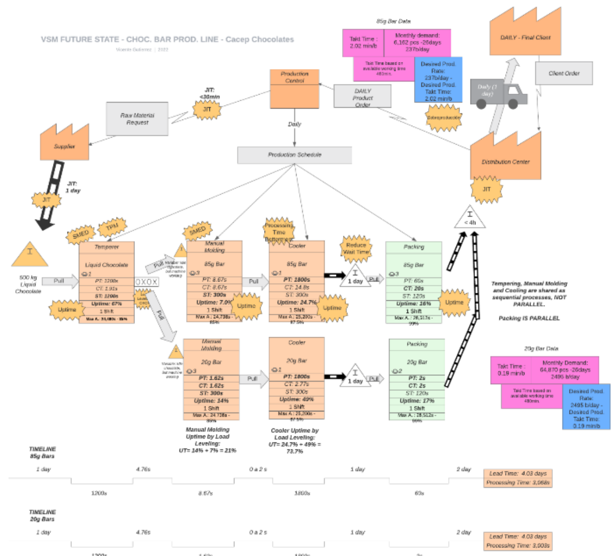

Figure 3 VSM Future State Map for 85g and 20g chocolate bars
Source: Author's contribution (May 2022)

The main objective of this Future State Map is to provide a guideline for the company to follow. This is a great tool to analyze where, how and when enhancements should be implemented. The practical explanation of this is shown in the discussion section. General results of Figure 3 are shown in Table 8.

Resulting Table of the production Line - General Data			
Parameters:	Temperer 85g-20g	Molderer 85g-20g	Cooler 85g - 20g
PT (s/bar)	1200	8.67 - 1.62	1800
CT (s)	1.91	8.67 - 1.62	14.8 - 2.77
ST (s)	1200	300	300
UT (%)	57%	7%+14% = 21%	24.7%+49% = 73.7%
Shifts	1	1	1
Max.A.T.A (s)	24480	24738	25200
Max.A.T.A (%)	85.00%	85.00%	87.50%

Table 8 General parameters results – Future State Map.
Source: Author's contribution (May 2022)

Discussion

In this section parameter obtention will be discussed, showing their relationship with the selected enhancements.

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CSM and FSM comparison

Tables 9 and 10 compare the CSM and FSM parameter values that were obtained for each processing module.

Comparative table for 85g bars Currents vs Future State Part 1.				
Parameters	Current Value Temperer	Future Value Temperer	Current Value Molderer	Future Value Molderer
PT (s/bar)	1200	1200	8.67	8.67
CT (s)	1.91	1.91	8.67	8.67
ST (s)	1800	1200	600	300
UT (%)	40%	57%	12%	7%
Shifts	1	1	1	1
Max.A.T.A (s)	21600	24480	23328	24738
Max.A.T.A (%)	75.00%	85.00%	81.00%	85.00%

Table 9 Comparative table: Current vs Future State parameters Part 1
Source: Author's contribution (May 2022)

Comparative table for 85g bars Currents vs Future State Part 2.		
Parameters	Current Value Cooler	Future Value Cooler
PT (s/bar)	2100	1800
CT (s)	14.8	14.8
ST (s)	300	300
UT (%)	42%	24.7%
Shifts	1	1
Max.A.T.A (s)	25200	25200
Max.A.T.A (%)	87.50%	87.50%

Table 10. Comparative table: Current vs Future State parameters Part 2
Source: Author's contribution (May 2022)

The main difference is the Uptime value for each of the processing modules. While the temperer shows an increase from 40% to 57%, the molderer and the temperer are reduced from 12% to 7% and 42% to 24.7% respectively.

The temperer shows a general increase. As these processes does not differentiate between 20g and 85g yet, as it processes liquid chocolate, both products are summed together for the temperer Uptime. Therefore, measurement for this parameter is higher. It is important to point out that temperer parameters are the same for both 85g and 20g bars.

In the case of the molderer and the cooler modules, 85g chocolate bar occupation was reduced to prevent overproduction. At the same time, 20g chocolate increased from 0% to 14% and 49% (molderer and cooler). As a general result, the total Uptime for the molderer accounts for 21.0% (7.0% + 14.0%) and the cooler for 73.7% (24.7%+49.0%).

Additionally, Processing Time was improved from 2100s to 1800 for the cooler, achieved through environmental enhancements, discussed in the following paragraphs.

Kaizen improvements implications

Besides the aforementioned parameter changes, there were other secondary improvements to the FSM. This will be explained through Kaizen event indications used in both figure 2 and 3.

Observed Kaizen factors are listed:

a) JIT (Just in time) and Wait Time.

Time delivery reduction for raw material requests (RMR), supplier delivery time (SDT), idle chocolate bars (ICB) and distribution center arrival (DCA). RMR reduced from 1 day to <30min; SDT, from 3 days to 1 day; ICB, 48h to 24h; and DCA, from 1 day to <4h.

This was achieved through the following:

i. RMR, SDT and DCA: Production programming was improved by teaching the production programmer about lean manufacturing and load leveling, instead of batch production. Also programming tools were provided such as blackboards, "monday.com" software and physical schedule planners.

ii. RMR, ICB, SDT AND DCA: Inter-area conflicts were reduced by implementing kaizen focused on organizational development: job rotation schedules, weekly education courses about values and teamworking (1h a week), training every 15 days, and daily five-minute meetings at the end of the day.

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iii. ICB: Two extra employees were hired dedicated to 85g bar packaging, eliminating the additional idle day.

b) SMED (Single Minute Exchange of Die) and Setup Time.

Introducing a new product to the line generates the need for changeover/setup time. Therefore, a technique for fast changes was needed, especially for the temperer that has the higher changeover/setup time.

i. Temperer: 3 bowls with 15kg liquid chocolate were prepared before the change of product took place. This allowed the operators to rapidly change between types of chocolate. This process was improved from 1800s to 1200s (30 to 20 min).

ii. Manual molding. Cleaning time for chocolate molds was reduced by assigning an operator specifically for this task. Also, changeover time was reduced by acquiring around 200 extra molds.

c) Load Leveling, Uptime and Overproduction.

i. Increase on production **Uptime** for all 3 modules. This was the major improvement to achieve optimization. It was done by adding an additional set of products (20g bars) to the line and reducing 85g bars Uptime. As a secondary solution, **overproduction** was eliminated, and the production rate was matched with the daily.

ii. The indirect solutions that also helped implementing Load Leveling are related to bullets (a.i) and (a.ii) from this section.

d) Cooling Processing Time.

i. Environmental conditions were improved by installing an additional air conditioner and a dehumidifier to the working station. This allowed to prevent temperature spikes during midday (up to 30°C max, reduced to 25°C max), and to control relative humidity during rainy days (50-60% relative humidity). This allowed cooler's processing time to be reduced from 2100s to 1800s. (35min to 30min), resulting into a lower general processing time (from 3,368s to 3,068s).

e) Lead Time

i. As RMR, ICB, SDT and DCA from point (a) contribute to reduce NVAT. The last is part of equation 13 that calculates Lead Time. Therefore, Lead Time value will be lower (from 8.03 days to 4.03 days).

f) General Processing Time.

i. Given that the cooling processing time was reduced, and general processing time is the sum of all processing times, a reduction for this parameter is shown in the FSM.

Conclusions

VSM has proven to be a very effective lean methodology for the analysis of relatively atypical processes such as chocolate bar products. In this research VSM allowed a major enhancement: increase of the cooling process general uptime by around 31.7% (from 42% to 73.7%) and, at the same time, preventing overproduction by introducing the Load Leveling Kaizen event. In practical terms, by processing two different types of products in the same line, 85g and 20g chocolate bars.

Main observed problems for the implementation were environmental conditions and lack of personnel performance. As a future enhancement, the company should invest on infrastructure in order to improve environmental conditions. A sealed room with controlled temperature and humidity are suggested.

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Personnel key competences are very relevant such as commitment, basic math and computer skills, empathy and to be open to work in teams. Kaizen applied to personnel behavior resulted of great importance, as it influenced most of the analyzed parameters.

Expected future work and analysis is to add more products, such as other varieties of 85g bars (8 types included now, but 15 are produced by GICSA), other varieties of 20g bars (8 types included now, but 20 are produced by GICSA) and 8g chocolate pieces (8 different types). Adapting new load leveling of products will increase general uptime and it is very likely that 2 shifts might be needed (also chocolate demand might increase, supporting this measure).

Further analysis will be carried on for this production line, but also the same methods will be used for chocolate drop depositing and packing production lines.

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