Efficiency Improvement in Wood Beam Line Process Using Lean Manufacturing Tools in the Peruvian Sawmill Industry

José Manuel López-Acosta
Faculty of Engineering, Industrial Engineering Career,
University of Lima, Peru
20153062@aloe.ulima.edu.pe

Juan Carlos Quiroz-Flores
Research Professor
Faculty of Engineering, Industrial Engineering Career,
University of Lima, Peru
jcquiroz@ulima.edu.pe

Abstract

The research aimed to improve the operational efficiency in the cutting process of a wood beamline in a Peruvian sawmill using Lean Manufacturing tools. The study found a technical gap of 11.81% with an economic impact of 4.94%. Three root causes were identified: breakdowns in the tableting machine, high setup times, and errors in the cutting process. To address these issues, the study proposed the use of engineering tools such as SMED and standardization of the work method. The implementation of these tools was expected to increase operational efficiency, reduce downtime, and improve product quality. The study's findings contribute to the literature on Lean Manufacturing and its application in the Peruvian manufacturing industry, highlighting the potential for efficiency improvements in the wood processing sector.

Keywords
Operational efficiency, Lean Manufacturing, Engineering tools, SMED, work method, standard time.

1. Introduction
Peru is the ninth country in the world with the greatest forest cover, more than 60% of its territory is covered by vegetation. The formal contribution of timber, the main forest product, to the national economy is only a small fraction of what it could be if timber were harvested sustainably, efficiently and with added value (Agricultura2018). According to INEI (2016), the operational efficiency in the manufacturing sector is 70%, this percentage is found in the 2016 statistical compendium of Peru, since the sectoral report is done every 10 years it is still possibleto use such data as a reference to compare our efficiency with that of the sector.

After evaluating the identified problem, root causes such as machine stoppages due to breakdowns, reprocessing, breakage in the stock of PM, and defective raw material were detected. This problem was also identified in other research, for example; in an article from 2021 it is seen that the study seeks to propose an alternative approach to improve the manufacturing setup time and time between failures, seeking to eliminateoutliers related to manufacturing setup times, performing simulations to compare the effect on lead time of both improvement strategies with traditional strategies of reducing the mean or variability (Utiyama et al. 2021). Another article of the same year talks about the implementation of the partial TPM methodology together with the 5's tool to increase the availability of equipment, where the novel sequence of application of tools allows the linking of lean with quality, highlighting that if applied in a correct sequence will allow solving persistent problems in a few steps resulting significant for companies (Marinho et al. 2021). The above- mentioned shows that wood companies(manufacturing sector) continue to have deficient processes while waiting for new industrial solutions to this problem.

The following case study presents the possibility of contributing to the operational efficiency in the cutting process of a timber company, where the percentage of this indicator in the year 2021 was 58.19%, which will be compared with 70% of the sector, with a technical gap of 11.81%. To solve the problems described above, engineering tools such as SMED and standardization of the work method are proposed.

1.1 Objectives

- Increase operational efficiency in the wood beam line process through the application of SMED tools andwork standardization.
- To design the improvement proposal for the wood beamline through an efficiency model in the cutting andtableting processes.
- Validate the solution using the improvement proposal with the proposed tools.
- Determine the economic feasibility to evaluate the profitability, sustainability and financial feasibility of implementing a new process in the wood beams market in the Peruvian context.

2. Literature Review

2.1 SMED

SMED (Single-Minute Exchange of Die) is an improvement tool that enables tool changeover times to be reduced considerably, resulting in increased flexibility, productivity, and efficiency. However, the implementation of this tool requires a training period in which one learns to distinguish between the different types of operations, to have the ability to transform internal operations into external ones, and to solve the problems that this poses, etc. (Miguel Ángel Gil García, 2012).

2.2 Standard work

In a project of the Peruvian University of Applied Sciences (UPC) of the year 2023, they made a report presented a study where the importance of continuous improvement tools and staff training as a mitigation strategy against non-fulfillment of orders is very important, production models were compiled through which could reduce downtime.
The proposed model consists of the implementation of a model applied to small companies without requiring large investments or state-of-the-art technology, and the reported results revealed that the instances of late non-fulfillment of orders were reduced by up to 19%, using the theory of constraints, with the adoption of Lean tools with scheduling in the industrial sector (Durand and Monzon 2023).

2.3 Lean manufacturing

The efficiency of Lean Manufacturing in waste reduction is well acknowledged, owing to the utilization of tools including 5S, TMP, SMED, and the Kanban System (Antosz and Dorota 2017). Its utility transcends the confines of manufacturing enterprises and provides strategies for enhancing operations across many occupational settings. Effective supply chain coordination is essential for ensuring materials are available on time, are of high quality, and are priced affordably. Furthermore, it can be incorporated into the company culture, so bolstering the business vision across all domains (Alvarado-Siete and Gómez 2022).

2.4 Preparation times

To compare the impact of conventional strategies of reducing mean or variability on lead time and time between failures, a 2021 study proposed an alternative method for enhancing manufacturing setup time and time between failures. To eliminate outliers associated with manufacturing setup times, simulations were utilized to assess the effect of both improvement strategies on lead time. The research is founded upon a low-variability simulation, and the approach prioritizes the average setup time and time between failures. It also presents a practical alternative with moderate variability, which can be attained at a reduced expense and with less effort through the application of manufacturing and operations management studies (Utiyama et al. 2021).

2.5 Standard time

It is the time it takes an employee to complete a task efficiently, taking into account supplementary and valuation factors, in addition to the standard that measures the time required to complete a unit of work by a worker with the necessary skills, developing a normal speed that can be maintained daily without exhibiting signs of fatigue, using standard methods and equipment (Toro 2020).

3. Methods

An examination of a company that specializes in supplying timber products sourced from reforested plantations will be the subject of this scientific article. The company is distinguished by its product diversification and dedication to the environment; it even has the slogan "Your partner in wood" and offers construction, hardware, heavy bodywork, home, accessories, and carpentry services (Guba 2022).

The present research is quantitative since it uses numerical, measurable, and quantifiable data, which are analyzed with a statistical and mathematical approach (Ramos 2022).
In this way, data can be collected and analyzed objectively through experimental designs to measure the impact of the variables and the validity of the proposed implementation (Cardenas 2018).
In a 2017 article published in Bogota, the authors highlight the importance of being an applied science, to migrate towards more adequate conceptions, by solving the problem and validating the research method and results, being necessary to formulate the method that is hypothetical deductive and being the methodology in engineering research considered in an integrative and complex way (Gallego and Gonzales 2017).

Based on the causes identified, a problem tree was drawn up showing the root causes of the main problems present in the company.

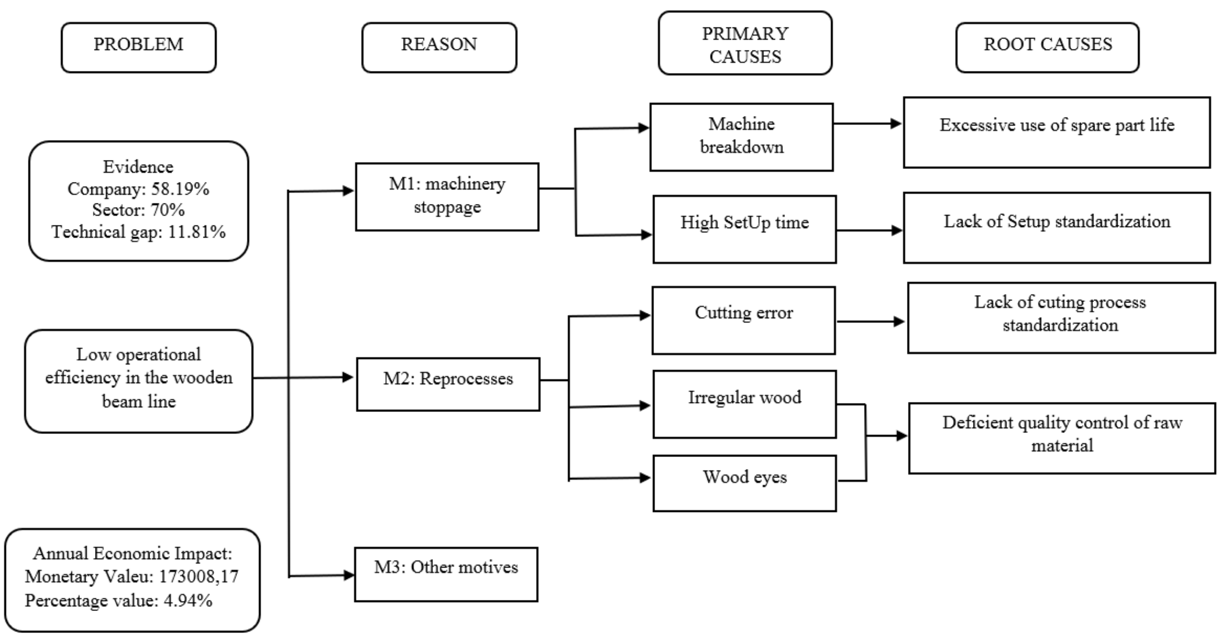

Figure 1. Problem Tree

To start with the analysis of the current situation, different information gathering tools were used. In addition to previously scheduled visits to the company's facilities, a short interview was conducted with one of the plant managers, which helped us to have a broader perspective of the business. We also made use of the Pareto tools and the Ishikawa diagram, which proved to be very efficient in identifying the main root causes. In the same way, a Value Stream Mapping (VSM) was used and elaborated in order to provide a detailed understanding of the process.

4. Analysis of the current situation

We will start by performing a time study to calculate the operational efficiency of the entire process.

Table 1. Development of the standard time and capacity of the design

Process	Weather	Constant supplements	Variable supplements										Final supplement	Supplementary factor	Standard time	Capacity	Station	Design capacity	Actual Capacity
			A	B	C	D	E	F	G	H	I	J							
Garlopa(2)	4.24	9%	2%	0%	1%	0%	0%	2%	0%	0%	0%	0%	14%	1.14	4.83	1	2	198.61	268.41
Thicknesser	10.47	9%	2%	0%	1%	0%	0%	2%	0%	0%	0%	0%	14%	1.14	11.94	1	1	40.22	46.78
Mitre saw	11.66	9%	2%	0%	1%	0%	0%	0%	0%	0%	0%	0%	12%	1.12	13.06	1	1	36.76	52.11
Bank circular	15.49	9%	2%	0%	1%	0%	0%	0%	0%	0%	0%	0%	12%	1.12	17.35	1	1	27.67	46.61
Belt sharpening machine	22.84	9%	2%	0%	1%	0%	0%	0%	0%	0%	0%	0%	12%	1.12	25.58	1	1	18.76	71.86
Blade sharpener	21.85	9%	2%	0%	1%	0%	0%	0%	0%	0%	0%	0%	12%	1.12	24.47	1	1	19.61	71.29
Tableting machine	129.8	9%	2%	0%	1%	0%	0%	0%	0%	0%	0%	0%	12%	1.12	145.38	4	1	13.21	52.76

Then:

Efficiency = (Actual capacity) / (Design capacity)
Efficiency = 354.84/609.8
Efficiency = 58.19 %

Based on the information provided and determined, a Value Stream Mapping (VSM) was elaborated with the objective of knowing in detail the complete process of the production of wooden beams from the reception of theraw material to the arrival to the final customer.
The number of operators per process, cycle times and lead time were taken into consideration.

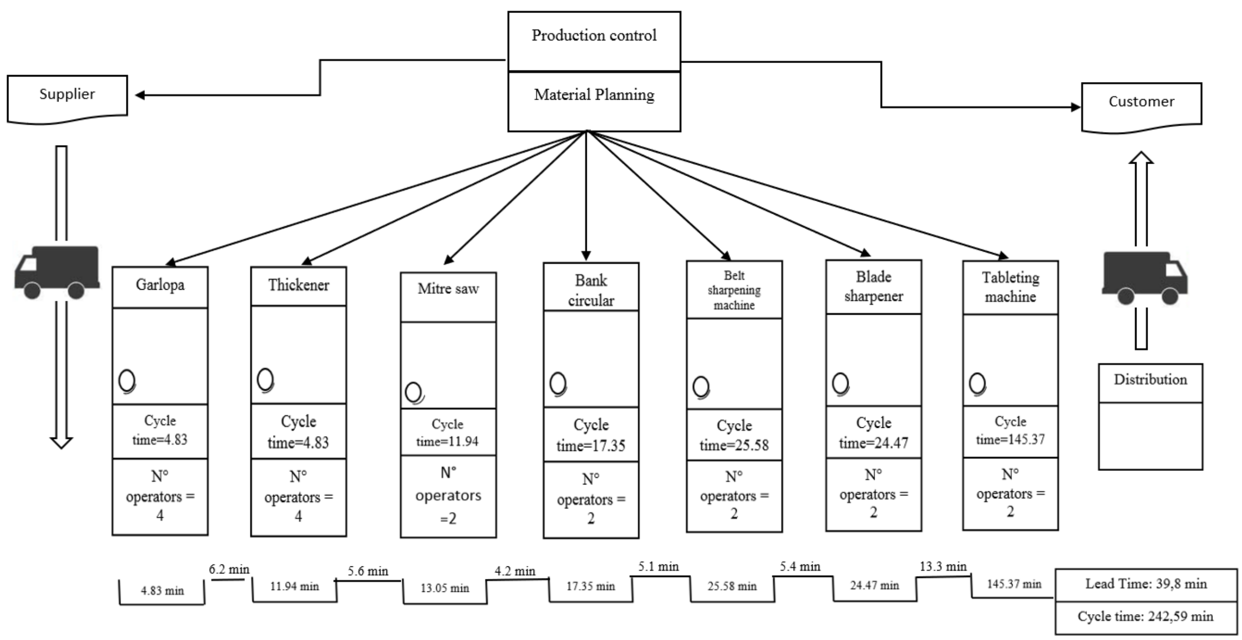

Figure 2. Company's current VSM

Similarly, a Pareto diagram was made quantifying the reasons that explain the low efficiency in the company Guba, for which the information obtained during the period of one year (2021) is compiled, in order to determine the main reasons.

Table 2. Time generated by reason

Month	Time (hours)			
	Machine stop	Reprocesses	Breakage of raw material stock	Defective raw material
January	5.04	4.09	1.33	1.39
February	5	4.34	1.6	1.41
March	5.21	4.24	1.35	1.27
April	4.97	4.27	1.6	1.37
May	5.22	4.21	1.63	1.43
June	5.1	4.24	1.67	1.37
July	5.21	4.02	1.45	1.25
August	5.22	4.24	1.64	1.25
September	5.27	4.4	1.07	1.32
October	4.63	4.07	1.68	1.34
November	5.13	3.87	1.39	1.45
December	4.69	4.05	1.68	1.33
TOTAL	60.69	50.04	18.09	16.18

See The table on times generated by reasons shows that the highest value is in September for the number of machine stoppages, 5.27 hours, with reprocesses of 4.40 hours.

Table 3. Time generated by reason

CAUSES	Time	Percentage (%)	% Accumulated
Machine stop	60.59	42%	42%
Reprocesses	50.04	35%	76%
Breakage of raw material stock	18.09	12%	89%
Defective raw material	16.18	11%	100%
TOTAL	144.9	100%	

The table shows an accumulated percentage according to prioritized causes, the highest value being the cause of machinery stoppages with 60.69 hours, representing 42%, reprocesses with 50.04 hours, corresponding to 35%, and defective raw material with 16.18 hours, representing 11%.

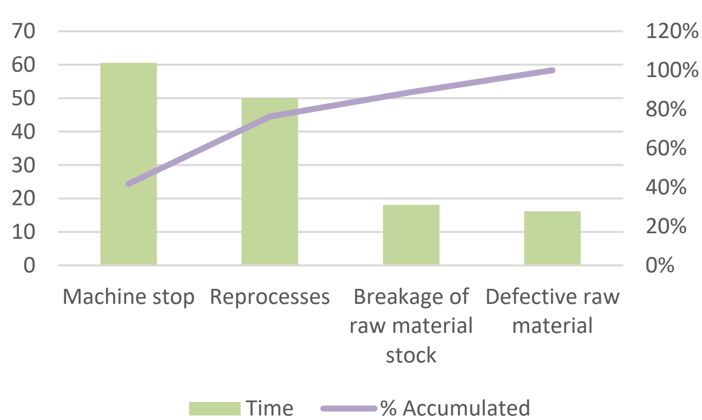

Figure 3. Pareto Diagram

In the Pareto diagram, it can be seen that the main problem detected in the analysis is machinery stoppages, which amounts to 60%, followed by reprocesses, breakage in the PM stock and finally, with a lower but significant value, defective raw material.

After determining the main reasons for solving the problem in question and in order to carry out a complete analysis of the current situation of the company with respect to the low percentage of Operational Efficiency, an Ishikawa diagram was developed, which allows identifying the main causes of the problem in question.

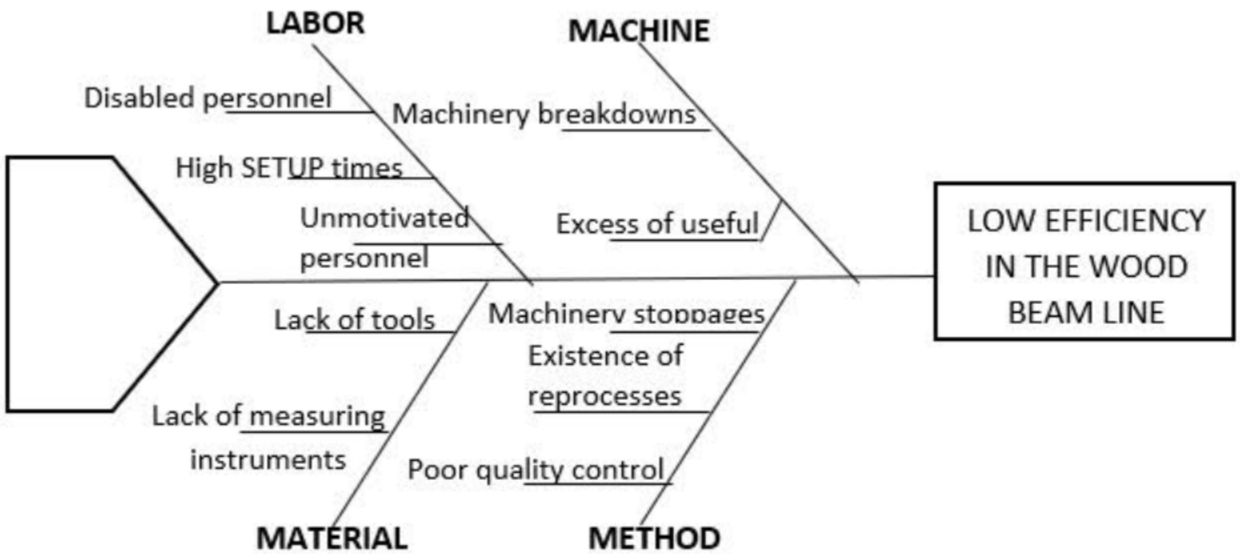

Figure 4. Ishikawa diagram of the timber company under study.

5.3 Results

The VSM shows a cycle time of 242.59 minutes and a lead time of 39.8 minutes, the most critical process being the tableting machine with a time of 145.37 minutes.

The SMED tool in the company would be oriented to the second root cause of the problem, which mentions that in the preparation of the tableting machine there is a variation in the setup times. To this end, the setup activitiesalready established by the operators for this process are identified. In addition, time is taken to evaluate each internaland external activity performed in the configuration. The following table shows the configuration activities.

Table 4. Total setup time of the tablet press machine

N°	Activity	Duration	Process	Transport	Wait	Others	Internal time	External time
1	Search tools	00:02:00		X			X	
2	Search for protective equipment	00:02:00		X			X	
3	Calibrate measurements	00:01:00	X				X	
4	Set rollers	00:05:00	X				X	
5	Set band saw	00:00:30	X				X	
6	Measure wood	00:03:00				X	X	
7	Set up base wood	00:00:20	X				X	
8	Turn on the sliding table machine	00:00:05	X				X	
9	Turn table saw off	00:00:05	X				X	
10	Inspect	00:01:05	X					X
Time		0:15:05	00:08:05	00:04:00	00:00:00	00:03:00	0:14:00	00:01:05
Percentage		100%	53.59%	26.52%	0.00%	19.89%	92.82%	7.18%

Table 5. Sampling of total setup time of the Tablet Press machine.

Machine		Tablet machine				
Made by		Operator				
Date		1	2	3	4	5
Sample						
N°	Activity	Duration	Duration	Duration	Duration	Duration
1	Search tools	00:02:00	00:02:15	00:02:00	00:02:00	00:01:47
2	Search for protective equipment	00:02:00	00:02:12	00:02:00	00:02:00	00:02:26
3	Calibrate measurements	00:01:00	00:01:00	00:01:00	00:01:00	00:01:00
4	Set rollers	00:05:00	00:04:35	00:05:20	00:04:43	00:05:00
5	Set band saw	00:00:30	00:00:30	00:00:30	00:00:30	00:00:30
6	Measure wood	00:03:00	00:03:00	00:03:00	00:03:23	00:03:00
7	Set up base wood	00:00:20	00:00:28	00:00:28	00:00:20	00:00:20
8	Turn on the sliding table machine	00:00:05	00:00:05	00:00:05	00:00:07	00:00:07
9	Turn table saw off	00:00:05	00:00:08	00:00:12	00:00:05	00:00:08
10	Inspect	00:01:05	00:01:17	00:01:05	00:01:05	00:01:05
Time		0:15:05	0:15:30	0:15:40	0:15:13	0:15:23
Reviewed by						

As shown in Table 5, the total setup time of the tablet press is 15:05 min, where 92.82% of the time is composed by internal activities and the rest by external activities.

For the implementation of SMED, it was defined as shown in Table 6 that the search for tools, search for personal protective equipment (gloves, goggles, and earplugs), and measurement and placement of the base wood, are external activities.

Table 6. SMED implementation

N°	Activity	Duration	Internal time	External time	Remarks
1	Search tools	00:02:00		X	Perform before change
2	Search for protective equipment	00:02:00		X	Perform before change
3	Calibrate measurements	00:01:00	X		
4	Set rollers	00:05:00	X		Improve method
5	Set band saw	00:00:30	X		
6	Measure wood	00:03:00		X	Perform before change
7	Set up base wood	00:00:20		X	Perform before change
8	Turn on the sliding table machine	00:00:05	X		
9	Turn table saw off	00:00:05	X		
10	Inspect	00:01:05		X	

Finally, the standardization of the work will be carried out in the cutting machine of the process, it will be implemented in order to teach the personnel the sequence of activities to be followed, under an industrial engineering criterion. This tool is focused on reducing reprocesses due to errors in the cutting process, for which the following steps are executed:

- Generation of worksheets: In this stage, the activities to be performed in the cutting process by allresponsible personnel are detailed and specified. The information generated from the previous analysis and the time study is used as a reference, thereby recognizing the non-standardized activities and placing them as part of the process activities.

Worksheet		Cod		Ht - 01
Made by	Plant Manager	Area: Cutting		
Raw Materials	Wood	✚ Security	◆ Quality Inspection	
N°	Operation	Symbol	Manual time	Transfer time
1	Visual verification of components	◆	00:03:00	
2	Set gallop	✚	00:05:57	
3	Verification of blades	◆	00:02:05	
4	Move and control table height		00:01:00	
5	Remove accessories	✚	00:00:15	
6	Use personal protective equipment	✚	00:00:05	
7	Clear work area of gallop		00:00:15	
8	Receive wood		00:01:00	
9	Inspect wood		00:00:45	
10	Mark cutting area	◆	00:00:35	
11	Place wood free of defects and marked on machine		00:00:20	
12	Start the cutter		00:00:05	
13	Set cutting speed		00:05:00	
14	Make cuts		00:00:30	
15	Turn off the blade		00:05:00	
16	Inspect cut wood	◆	00:00:05	
17	Take products to next station		00:02:00	00:03:00
Total			00:22:57	00:03:00

Figure 5. Standard worksheets

With the definition of the procedure, it must be exposed and explained to the personnel who are part of the cutting process, which is in charge of the supervisors, for this purpose, training was carried out and the exposed worksheets were published.

Multiservices for Timber Guba S.A.C	ATTENDANCE RECORD GENERAL INDUCTION, TRAINING OR OTHER					Code	M.MG.1896
						Versior	3
						Date	15/12/2023
						Page	1 OF 1
EMPLOYER´S GENERAL DATA							
Company name GUBA	RUC: 20604372691	Tax domicilie: Av Huarochiri, manzana B1, Santa Anita 15011				Economic activity: Manufacture of wood products	
Name and Last Name (Responsable)		Process/Area (Responsable)		Position		Firma	
-		ADMINISTRATIVE		MANAGEMENT MANAGER		-	
ACTIVITY DATA - TRAINER DATA							
Start date	17/12/2023	Start time (am/pm)	09:00	Duration time	Hours		
End date	17/12/2023	End time (am/pm)	09:45		Minuts	45	
Name and Last Name		DNI	Company name			Signature	
Cutting supervisor		-	GUBA S.A.C			-	
TYPE	**Check "X" where applicable**						
Induction			Subject				
Training		X	Subject	New standard procedure			
Dialogues			Subject				
Committee			Subject				
Meeting			Subject				
Others			Subject				
SUMMARY OF THE SUBJECT MATTER							
Presentation and explanation of the activities added in the cutting process							
PARTICIPANTS:							
N°	CODE	ame and Last Nan	Position	Area	DNI	Signature	
1	834	-	Operator	Cut	-	-	
2	7621	-	Operator	Cut	-	-	
3	438	-	Operator	Cut	-	-	
4	4637	-	Operator	Cut	-	-	
5	6698	-	Operator	Cut	-	-	
6	8829	-	Operator	Cut	-	-	
7	4677	-	Operator	Cut	-	-	
8	4387	-	Operator	Cut	-	-	
9	4186	-	Operator	Cut	-	-	
10	7896	-	Operator	Cut	-	-	
11	768	-	Operator	Cut	-	-	
12	4675	-	Operator	Cut	-	-	
13	346	-	Operator	Cut	-	-	
14							
15							

Figure 6. Training attendance record

After the application of the tools, a new time measurement was performed, considering a new sample of 30 items to determine the standard time and capacity after the implementation of the improvement proposal. The result was the following table.

Table 7. Calculation of the actual total capacity and design of the wood beam production line after implementation

PROCESS DETAIL	CAPACITY
Garlopa(2)	268.41
Thicknesser	46.78
Mitre saw	52.11
Bank circular	46.61
Belt sharpening machine	71.86
Blade sharpener	71.29
Tableting machine	52.76
DESING CAPACITY	609.82
REAL CAPACITY	427.04

Efficiency = (Actual capacity) / (Design capacity)
Efficiency = 427.04/609.8
Efficiency = 70.01%

With the improvements proposed and after carrying out a time study, it was observed that the technical gap was reached, an efficiency of 70.01% was reached, equaling the percentage of the sector, so it can be concluded that the improvements had a positive impact on the problems.

6. Conclusion

With the analysis of the current situation of the company, it is shown that through the implementation of the improvement proposal the company does not adequately use the opportunities to counteract the threats and in addition to this it has a weak reaction to its weaknesses.

Through the use of the VSM tool, it was identified that the company recognizes that the most deficient processes are in the area of wood-cutting machinery, specifically the table saw, including setup time and errors made by workers at the time of cutting.

With the application of the Lean Manufacturing tools, the main root causes were determined, the first cause to be solved is the breakdowns in the tableting machine, which represents 21.23%, the second cause to be solved is the high setup times that represents 20.63% and finally, the presence of errors in the cutting process in 19.08%.

It is determined through the implementation that the project investment is recovered in 1.29 years, so the proposal is not only supported by the improvement in the indicators but also in the economic viability.
The implementation of the improvement proposal is feasible since it has an Annual Net Value (NPV) of s/116,478.88 and an Internal Rate of Return (IRR) of 74.55%, values that demonstrate that the project is profitable since the NPV must be greater than 0 and the IRR greater than the Opportunity Cost (COK).

References

Antosz, K. Dorota, S., Implementation of Lean Philosophy in SMEs - Study Results. *Procedia Engineering,* vol.*182*, pp. 25-32, 2017.

Alvarado, L. and Gomez, L., Service management model based on Lean and Kaizen tools to improve the level ofsatisfaction in health sector companies, 2022.

INEI. Digital *publications.* https://www.inei.gob.pe/biblioteca-virtual/publicaciones-digitales/, October 10, 2016.

Utiyama, MHR, Godinho Filho, M. and Oprime, An alternative to improve setup times and time between failures with the goal of reducing manufacturing lead time, https://doi.upc.elogim.com/10.1007/s11740-021-01048-0, 2021.

Marinho, P. Pimentel, D. Casais, R. Silva, R and Sá, J.C. Selecting the best tools and framework to evaluate equipment malfunctions and improve the OEE in the cork industry. *International Journal of Industrial Engineering and Management, 12(4)*, 2021.

Durand, L. and Monzon, M. Improvement proposal to reduce the delivery time of orders in a textile manufacturing MSE using Lean tools and work study, *Repositorio Universidad Peruana de Ciencias Aplicadas, 2023.*

Guba. Your construction partner. Retrieved: https://maderasguba.com/nosotros/, 2023.

Ramos, P. Definition of quantitative research. Retrieved: https://www.lifeder.com/metodo-cuantitativo/:, Spain,2023.

Cardenas, J. Graduate Program in Sustainable Development and Social Inequalities in the Andean Region. Retrieved: https://refubium.fu-berlin.de/handle/fub188/22407, 2018.

Gallego, A. and Gonzales, R., Metodologia de la investigacion en Ingenieria, *Revista Cientifica*, vol. 29, Bogota, 2017.

Gil, M. Definition of a methodology for a practical application of SMED, Retrieved: https://www.tecnicaindustrial.es/definicion-de-una-metodologia-para-una-aplica/, June 12, 2012

Toro, E. Methods engineering. Retrieved: https://ingmetodosetoro2013.blogspot.com/2016/02/el-estudio-de-tiempos-y-movimientos.html, February 7, 2020

Abu,. Pathways of Lean manufacturing in the wood and furniture industries: a bibliometric and systematic review,753-772, Lima, 2020.

Aucasime, P. and Tremolada, S., "Waste elimination model based on Lean Manufacturing and Lean Maintenance for increasing efficiency in the manufacturing industry". Retrieved: URI http://hdl.handle.net/10757/652114, Lima, 2020.

Chuchullo, J. and Valencia, J., Modelo de producción basado en Lean TOC para la reducción de desperdicios en la industria de madera, *repositorio Universidad Peruana de Ciencias Aplicadas (UPC),* http://hdl.handle.net/10757/654621.:, Lima, Peru, 2021.

Biographies

José Manuel Lopez Acosta is a bachelor's in industrial engineering from the University of Lima. Currently working in ARCA CONTINENTAL LINDLEY

Juan Carlos Quiroz-Flores is an MBA from Universidad ESAN. Industrial Engineer from Universidad de Lima. PhD in Management and Business Administration at Universidad Nacional Mayor de San Marcos, Black Belt in Lean Six Sigma. Current is Undergraduate teaching at Universidad de Lima. Expert in Lean Supply Chain and Operations with over 20 years of professional experience in the direction and management of operations, process improvement and productivity; specialist in the implementation of Continuing Improvement Projects, PDCA, TOC and Lean Six Sigma. Leader of transformational projects, productivity and change generator. Capable of forming high-performance teams, aligned to company strategies and programs for "Continuous Improvement". He has published journal and conference papers and his research interests include supply chain management and logistics, lean manufacturing, lean six sigma, business process management, agribusiness, design work, facility layout design, systematic layout planning, quality management and Lean TPM. He is member of IEOM, IISE, ASQ, IEEE and CIP (College of Engineers of Peru).