Production optimization model to increase order fulfillment by applying tools under the Lean Green philosophy and TPM in plastic manufacturing SMEs.

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Abstract- The plastic sector sustains an important growth based on production worldwide and nationally during the last years. However, this growth in production can be affected by the various problems that the sector sustains, harming the availability of plastic products and thereby affecting customers, this impact is reflected in customer losses due to the non-fulfillment of orders or additional payments for penalties imposed by them. In this context, companies in the plastic sector aim to reduce machine downtime rates to increase availability and thereby maintain smooth production and thus increase the order fulfillment rate. After the above, in the research, the problem that generates a low rate of order fulfillment is due to the constant blowing machine shutdowns in the plant. Therefore, it is proposed to design a model based on the Lean Manufacturing philosophy, using tools such as 5S, SW, TPM and SMED, based on applications of the Lean Green philosophy; with the aim of reducing stops in the blowing machine making it more efficient and environmentally friendly. This research emphasizes the most representative product of the company, the drums, developing the diagnosis in the blowing process, which, the root causes were quantified with respect to the main problem, through the tools of the Lean Manufacturing philosophy it is proposed to address each cause and mitigate them. Finally, the model that has been proposed manages to reduce the rate of machine shutdowns by 55.48%, giving greater availability to the blowing machine and with it a better production flow, which generates an increase in the order fulfillment rate by 74.59%. In this way, a precedent is achieved in the plastic sector regarding the improvement of blowing processes.

Keywords-- **Plastic industry; Blowmolding machine; 6R; TPM; SMED**

I. INTRODUCTION

Currently, the production of international companies in theplastics industry is 348 tons, an increase of 3.8% over the previous year, which is also the value of global plastics production. At the national level, the production of the plastics item increased 4.5% in 2018, representing 4% of the industrial GDP and generating more than 200,000 jobs. Likewise, the manufacturing of plastic products continued to grow in 2019, with an increase of 11.2% and an average annual growth rate of 2.2%. 2020 was impacted by COVID 19, so the industry's percentage change decreased by 16.38%. However, it remained in the international and domestic market, as several products are used for the food industry[1]. Despite the growth of the sector based on production levels, the plastics industries present challenges such as high setup times, machines with low efficiency, non-fulfillment of orders and delays due to the order and cleanliness of the sector[2]. As a result, plastics companies are constantly looking for corrective actions to mitigate the causes and reduce costs.

After the above, non-fulfillment of orders is identified as one of the most representative problems, since, through literature review, it was found that a company should have a standard of 80% fulfillment due to the quality of products it provides [3]. Likewise, having an incorrect order fulfillment management involves penalties due to customer nonconformity [4]. So, in order to increase the delivery fulfillment rate in industries, several authors present solution tools. First, the case study of a plastic company was analyzed, where the Lean Manufacturing philosophy was used, eliminating penalties of S/ 20,520.81, overtime costs of S/ 4,920.81 and increasing order fulfillment from 58% to 95% [4]. In second place, there is a company that uses the Lean Manufacturing philosophy through the VSM tool, achieving an increase in order fulfillment from 94% to 100% and a Lead Time reduction from 4.5 days to 4.42% [5]. In third place, the TPM tool is used to improve the availability of machines in a metal-mechanic company, achieving an increase of 85.6%; initially,the value was 74.3% [6].

In this way, there is evidence of successful cases of the Lean Manufacturing philosophy in industries; however, withrespect to the plastics sector, the evidence of its application isminimal. Therefore, this research aims to validate the Lean Manufacturing methodology in the plastics sector to reduce setup times, unplanned stops in machines, delays in operator activities, under the design of a model that uses 5S tools, Standardized Work (SW), Autonomous Maintenance and SMED as remediation to the causes and finally meet the objective of increasing the rate of order fulfillment in the plastics industries.

The project is structured as follows: Section II contains the State of the Art divided into 5 typologies. Section III contains the research contribution and then, in section IV, the validation of the proposed model is presented. Finally, section V presents the conclusions of the article.

II. STATE OF THE ART

2.1. Order fulfillment management in the plastics industry

Order fulfillment management is important for the industry because it is possible to measure the amount of delivered and late products, to quantify in monetary value the penalties and to analyze the causes of delays [7], [8] For this, tools such as Value Stream Mapping (VSM) are used as a starting point, since this tool is responsible for capturing the information flow of the processes and their variables such as Work In Progress (WIP)

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and Lead Time to determine if the quantity of products will be finished on the planned date [5]. Evidence that supports this is the case of an automotive company where thereare late deliveries due to a high rate of defective products, to reduce this, they use the Lean Manufacturing philosophy through a VSM, by identifying the failures in the processes and taking corrective measures, the WIP, Lead Time and OTD indicators achieved an increase of 94.53%, 98.25% and 6.38%respectively. Thus, the authors demonstrate the relevance of the tools in the manufacturing sector; however, the evidence in theplastics sector on order fulfillment is minimal.

2.2. Application of Lean Manufacturing in the manufacturing process

- **Single Minute Exchange of Die (SMED) in the plastics and/or similar sectors:**

The SMED tool is based on 4 phases that allow mapping, identifying internal and external activities and, evaluating their elimination or combination, since, the main objective is to reduce setup times [9].

A case study shows that the application of the tool generates the reduction of preparation times from 45 minutes to 23minutes. A similar study shows that, in a plastics company, the transformation from internal to external activities in an injection molding process generates a reduction of 4.84 minutes.

- **Standardization of work (SW) in the plastics sector and/or similar:**

The standardization of work (SW) presents an approach of identification, evaluation and elimination of activities that do not generate value to the processes. Likewise, in order tostandardize, formats and guidelines are presented to the operators to avoid performing the same activities, thus obtaining reductions in the entire process [10]. A case study demonstrates the above, since 16 activities that did not add value to the processes are eliminated, achieving a productivityof 6.5% and a reduction in processing time of 44.4 minutes. Similarly, in a similar case, the results of the implementation ofthe tool obtained an increase in production of 42.62%.

- **5S in the plastics and/or similar sector**

The 5S tool presents an approach to maintain order and cleanliness in workplaces, increasing the safety and efficiencyof operators, also contributes to the reduction of time activitiesand transfers in aisles [11], [12].

A case study demonstrates the application of 5S in a manufacturing company, in which unnecessary elements are eliminated within the plant, tools are classified, cleanliness is applied to the workstations and finally a cabinet is designed to place the tools. In this way, productivity was increased by 4%, and distances were reduced by 205.3 meters through software simulations.

2.3. Application of TPM (Autonomous Maintenance) in the manufacturing process

The autonomous maintenance pillar aims to generate the initial cleaning and inspection of machines and equipment with the purpose of avoiding breakdowns and thus, increasing their efficiency [2], [13].

According to a study, the implemented tool has generated areduction of unplanned stoppages in a footwear plant as a result of the operators' quick recognition of recurring failures. A 72.2% reduction in failures and a 5% increase in production was achieved [14]. Another study shows that the maintenance plan in an automotive plant resulted in a reduction of repair time from 5.26 to 4.56 hours and extended the time between failures from 124 to 155 hours [15].

Despite the fact that the autonomous maintenance pillar is frequently used in manufacturing industries, there is not much information in the literature on autonomous maintenance plans in plastic industries, with emphasis on blow molding processes, due to this, it is intended to expand the knowledge of the tool in the sector, with the objective of mitigating recurrent failures in the machines.

2.4. Application of Lean - TPM models in the plastics industry

The TPM tool is responsible for the improvement on machine operation, increase of efficiency and avoidance ofunplanned stoppages in production processes [14].

According to a study, the implementation of TPM in a metalworking plant, achieved the increase of the OEE indicator from 63% to 74.3%, likewise, there was an increase of 85.6% in the availability variable [6]. Similarly, in a similar case study, TPM and TQM tools were used to mitigate machine stoppages, obtaining results such as the reduction of 1.5 hours per shift failure and an increase in the production rate of 89.48% [16]. That said, the authors mention the great importance of this tool in the manufacturing industries; however, the research carried out in the plastic sector, with emphasis on blow molding processes, is minimal.

2.5. Application of Lean Green models

The Lean Green philosophy aims to generate sustainability in companies through the optimization of resources without affecting the production capacity and reduction of emissions produced by machines [17], [18].

This philosophy uses tools similar to the Lean Manufacturing philosophy such as SMED, which, through a case study, achieved a 70% reduction based on the downtime found, then, eco-efficiency comparisons were made and demonstrated an 81% reduction in carbon emissions [19]. Another evidence is the application of the 6R tool, where the recovery and reuse of materials is used in a manufacturing company, this tool together with the Lean Manufacturing philosophy achieved the reduction of Lead Time, greenhouse gases and non-value-added times by 25.60%, 54.16% and 24.68% respectively [20]. Although the authors present improvements in their research with the implemented philosophy, there is minimal evidence in the plastics sector, therefore, we intend to address the philosophy and tools in the aforementioned sector.

III. CONTRIBUTION

3.1. Foundation

Fig.1 shows the proposed model to meet the objectives set out in the research. This is developed through models based on the Lean Manufacturing methodology [2], [9], [10], [13], [15], [18], [20], of which they are distributed through two components, the first part of an initial diagnosis through a VSM for information collection, after that, the tools for the quantification of each cause are part. On the other hand, the second component is based on remediation, that is, once the causes have been quantified, we proceed to use tools that allow mitigating or eliminating the causes found that directly affect the main problem. The application of the Lean Green

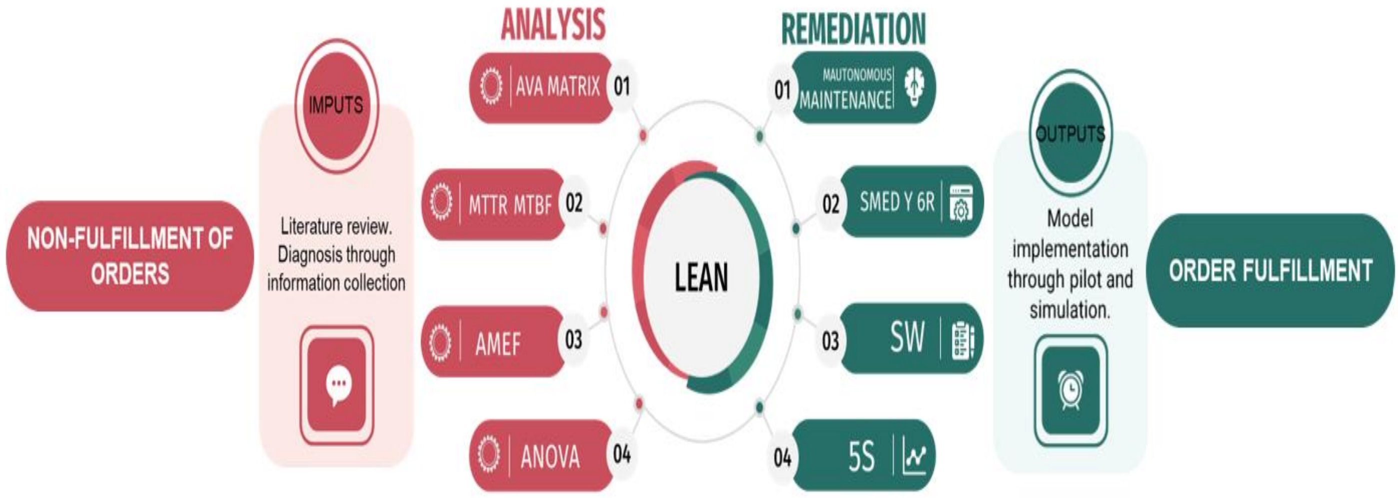

Fig. 1Deisgn of the proposed model adapted from [2], [9], [10], [13], [15], [18], [20]

philosophy through tools such as 6R during the waste selection stage contributes to the novelty of this model.

It should be noted that the realization of the proposed model comes from an exhaustive search for articles that stand out in the manufacturing industry, classifying 5 components for the construction of the contribution; the reduction of machine deficiencies: according to different authors, the problem could be excluded by TPM AND SW, the optimization of worker performance: this inconvenience could be eliminated with the SW tool, the reduction of clamping times due to inadequate order of the tools: this problem would be reduced with the support of the 5S tool, the reduction of hopper filling: it would be supported to exclude the problem and improve the reprocessing of the raw material with the innovative combination of SMED-6R and the optimization of cleaning standards in the machines: it would be executed with autonomous maintenance. Likewise, for the justification of the contribution and model made, a step-by-step diagram was used to highlight the construction of the contribution (fig.2)

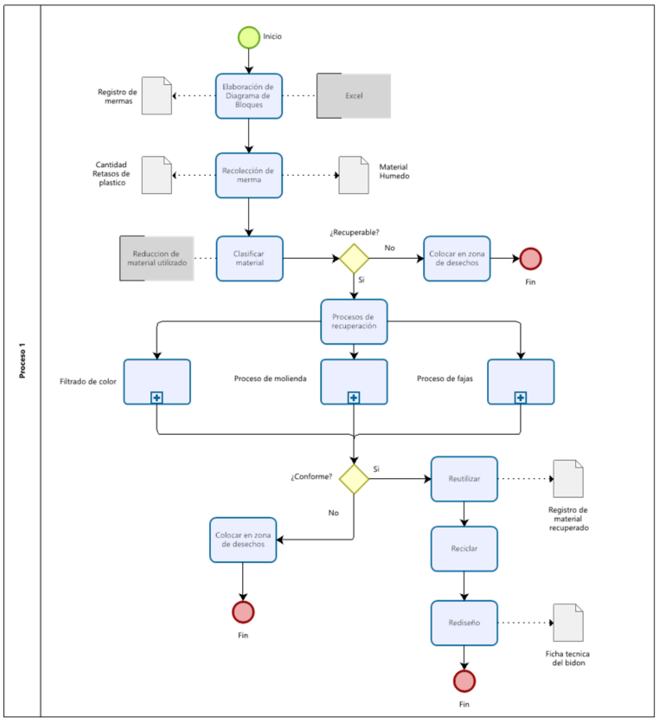

Fig. 2 Steps for the construction of the adapted contribution of [18], [20].

3.2. Proposed model

Through the analysis carried out in the research, it was possible to find that the main problem that the company has was the non-fulfillment of orders, since it has a value of 69.11%, which is below the standard, which is 80% according to the literature review. Also, after the analysis, it was identified there are stops in the blowing process, this leads to 84.115% of the main problem, through the OEE analysis, it was determined that the availability indicator had 78.76%. Due to this previous diagnosis, 2 first causes were determined, the first, the deficient regulation of the blowing machine and the second, the delays of the placement of the mold, giving opening to 2 root causes for the first and 3 for the second. Regarding the two root causes of the deficient regulation of the blowing machine, these are: The delay in the calibration of the machine, which obtained a value of 27.20% of activities that did not generate value, also, the following root cause, incorrect performance of the operator, there are dispersions based on calibration times in an average of 4.59 minutes. Regarding the 3 root causes of the delays in the placement of the mold, there is the delay in the fastening of chops due to lack of tools, which, through an initial audit, a score of 26 was obtained, the excess of setup times whose value in external and internal activities was 204.98 minutes and.

Finally, the delay in cleaning the blowing machines, which generated breakdowns and with MTBF and MTTR values of 47.24 and 1.79 hours respectively, also, 33.3% of functions remain at risk.

Taking into account the initial diagnosis and quantitative analysis of each cause, a Lean Manufacturing model has been designed to reduce machine downtime and thereby increase the order fulfillment rate. Although there is evidence of improvement in the manufacturing sector, we want to contribute in the plastic sector to the improvement of blowing processes and in this way, meet the demands imposed by customers. It should be noted that this model contains a novel section, which consists of the generation of sustainability in the plastic industries using the 6R tool, in this way, it is intended to collect plastic waste once the blowing process is finished and thereby move to material evaluations, that is, if the material is in good condition, this can go through a recovery process and with it go through the blowing process again, in this way, more drums can be produced and as a result address the same objective, which is to increase order fulfillment.

This model aims to identify the problems caused by machine shutdowns during the production process, based on engineering tools such as 5S, SW, SMED and TPM that seek to mitigate the causes of the stop rate.

3.2.1. Componet 1: Analysis

- ***Inputs***

In this section what is sought through the review of the literature is to identify antecedents of problems in the plastic sector, in this way, it can be analyzed how the authors made their diagnoses to identify the main causes and what engineering tools they used. With the information obtained, we proceed to collect data in the company where the research is carried out, in this way, through analyzing the variables obtained, we proceed to make comparisons with standards and define the main problem and after that identify the causes.

- ***Analysis***

In the analysis section, engineering tools are used to quantify the causes found during the development of the main problem. First, to address the root causes, delay in the calibration of the machine and incorrect performance of the operators, an AVA matrix was made, in which all the activities and their respective times were placed.

Likewise, the activities were classified, that is, those that add value, those that do not add value and those that do not add value, but are necessary in the process, all through the acronym VA, NVA, NNVA respectively. With this, it was identified that there are activities that do not add value in the process and activities that have high times, then, to perform the validation of the above, personnel are selected to perform the same activities and time taking is carried out. When the collection of times of these operators is completed, statistical methods such as ANOVA analysis are applied, through the approach, there are two hypotheses, h0: There is no difference in the methodology applied by the operator and h1: There is a difference in the methodology applied by the operator, once the test is carried out a $P < 0.05$ is obtained, which confirms a difference in methodology, that is, there are differences in the calibration of the machine performed by the three operators. The same happens with the performance regarding the activities carried out, the same steps are used and the same conclusion is reached, through a box diagram the differences in execution times are highlighted, which confirm a lack of standardization in the processes. On the other hand, to quantify the cause, delay in the fastening of chops due to lack of tools, a flow diagram is built where all the activities required for the placement of a mold are placed, including their respective times, it is terminated that the search for tools to perform the fastening activity is high, this is validated through audits where it is concluded that there are deficiencies in the work area.

Likewise, the root cause, excess of setup times, which is linked to the previous cause, is validated through statistical methods, in this case, again the ANOVA analysis is used, where it is concluded that there are high times.

Also, to perform the quantification of the cause, delay in cleaning the machine, maintenance audits are used where the current state of the company's maintenance management is evaluated, obtaining as a result, a low score, therefore, to validate this qualitative information, the calculation of MTBF and MTTR is carried out through a random selection of blowing machines.

Where data such as the number of stoppages due to breakdowns during a month, the time of the stoppage due to breakdown, the time lost due to scheduled stoppages and the theoretical working time are collected, in this way the 2 variables can be determined, and the state of the machines can be determined. These breakdowns can be cataloged under the construction of an AMEF matrix, where the failures in each section of the process can be analyzed and determine their level of severity, as well as establish at what level they are, that is, a stable, acceptable and critical level.

Once this was done, problems were identified in the cooling hoses, cylinders, nozzles of the machine, which generates obstructions when proper cleaning is not carried out, generating problems during production.

3.2.2. Component 2: Remediation

- ***TPM remediation***

This component was born to mitigate the cause of delay in cleaning the machine through 5 steps, these are: development of a cleaning and lubrication program together with the abnormal registration format; format for pollution sources; standardization of cleaning and lubrication of machines; banner for the realization of the follow-up trainings.

- ***SMED remediation***

This component seeks to attack the cause of excessive setup times, for this it began with the formation of the work team. Next, we proceeded with the current diagnosis where how many activities are currently classified; transformation of activities from external to internal either by combining or eliminating them; reduction of times; standardization by stages. Additionally, 2 more steps were added to give it a more environmentally friendly approach and thus be able to meet the objective of the research which is to meet the demand. Then the matrix of environmental impacts is elaborated and finally the implementation of the 6Rs (Reduce, Reuse, Recycle, Recover, Redesign, Remanufacture) is identified and classified.

- ***SW Remediation***

SW will be applied to address the standardization tool at work based on 4 simple stages. First, the DAP of the current process of the company is built to continue with the definition and classification of the activities that generate value and those that do not. After implementing an action plan and finally the evaluation and standardization of the process is carried out.

- ***Remediation by 5S***

This component is born to mitigate the cause delay in the fastening of chops due to lack of tools, to start with each S a preliminary diagnosis will be made. Next, we start with Seiri which is to classify the machines and objects that must be relocated or be directed to maintenance; Seiton which means to order the production areas; Siso that gives reference to cleaning through cleaning schedules; Seiketsu refers to standardizing the processes that have already been improved and finally Shitsuke which is the self-discipline that refers to continuing with the S already implemented.

3.3. Model indicators

This article will use metrics that allow the measurement of the tools used during the project.

- **On time delivery (OTD)**

According to the literature review, a lean manufacturing model can improve order fulfillment rates by 87.5 % [3], [4]

$$OTD = \frac{Number\ of\ on-time\ deliveries}{Number\ of\ total\ deliveries}. \quad (1)$$

- **OEE**

According to the literature review, the model to be implemented can improve OEE by 85%. [6], [15]

$$OEE = Availability\ x\ Performance\ x\ Quality\ . \quad (2)$$

- **MTBF and MTTR**

According to a literature review, the Lean Manufacturing model can generate increases of 15.5 % and 16.65 % in relation to MTBF and MTTR [15].

$$MTBF = \frac{Time\ spent\ on\ the\ work\ (TW)}{Total\ N°\ of\ failures\ in\ the\ period}. \quad (3)$$

$$MTTR = \frac{Repair\ time}{Total\ N°\ ot\ interventions\ in\ the\ period}. \quad (4)$$

- **Reduction time through SMED**

According to the literature review, the Lean Manufacturingmodel can employ setup time reduction 17.77 approx [9].

T.T.A.=T. int. activities-T.of ext. activities (5)

- **Standardized Work**

Regarding the literature review, the SW measure adopted bythe Lean Manufacturing Model is based on eliminating non- value producing activities and comparing again the time [10].

- **5S Audit**

As for the literature review, to observe the impact of the tool, it must be demonstrated through training photos and pilot programs, however, the measurement is based on periodicaudits and must have a score greater than 80 [11].

IV. VALIDATION

4.1. Description of the scenario

The research project has used the simulation and pilot methods as validation, since it is intended to demonstrate the effectiveness of each tool according to the root causes found and thus, increase order fulfillment. For this purpose, the pilot validation of the 5S and TPM tools was carried out through photographic evidence that shows the current situation and laterthe improvement, use of elements that contribute to each tool and audits that record the improvement and follow-up of the application by the operators in the plant. On the other hand, the validation by simulation is performed with the SMED tools, using the blowing, cutting and milling processes, in addition tothis, the impact of the contribution will be presented in the research where the blowing, cutting and milling processes willbe used. Finally, the SW tool is used under the simulation method, using the reduction of activities that do not add value to the processes.

4.2. Initial diagnosis of the company under study

The manufacturing processes for making drums have constant machine stoppages that represent losses in the non-fulfillment of orders of S/. 970,084, which, in percentage value, represents an economic impact of 13.5% of total revenues in the 2021 period.

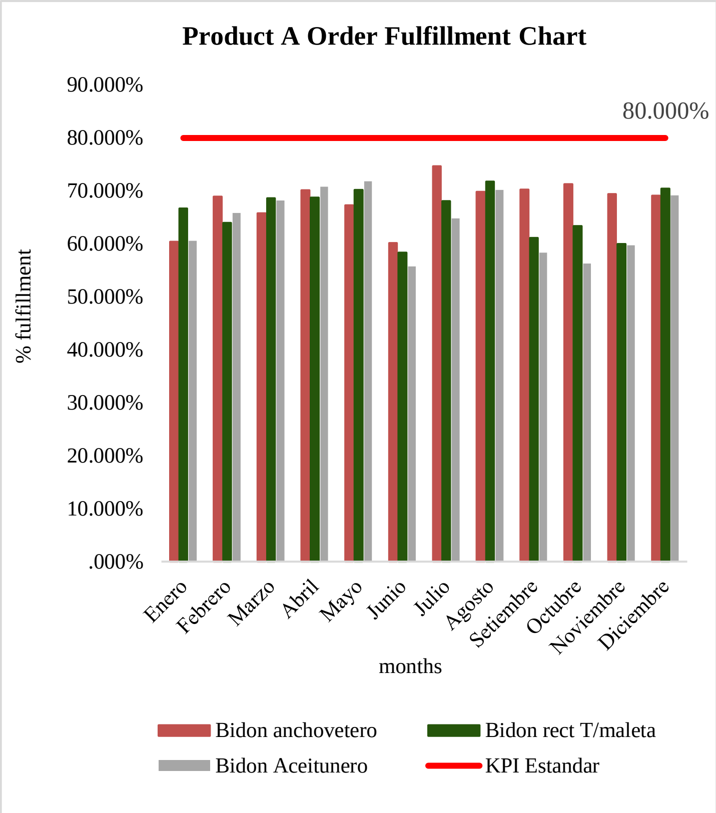

Fig. 3 Product a order fulfillment chart

4.3. Design and results

First, to apply the validation by pilot in the 5S tool (fig.4), red cards are implemented as they allow the classification of important tools in the workstations, also, its usefulness is also based on the elimination of unnecessary elements and relocations to certain areas.

ISSUE	SOLUTION

Fig. 4 PROBLEM AND SOLUTION FOR 5S

Then begins the cleaning of the workstations to eliminate unnecessary elements and obstructions in the aisles. Finally, the standardization of the mentioned activities is used (fig.5), which, through audits, a score of 86 is obtained.

HOJA DE EVALUACIÓN DEL TRABAJO ESTÁNDAR PARA EL PROCESO DE PRODUCCIÓN DE LOS BIDONES

Actividad crítica

Chequeo de calidad

Paso Nº	Secuencia de actividades	Tiempo ()	Cumple con los procedimientos SI	Cumple con los procedimientos NO
1	Generar la orden de producción del día	3.42	x	
2	Verifica si cuenta con lo solicitado	1.02	x	
3	Decepcionar los requerimientos de materia prima	2,04	x	
4	Ingresar los datos al sistema	1.05	x	
5	Recepción los requerimientos del molde	1.71	x	
6	Verifica las especificaciones del molde	0.29	x	
7	El operario verifica las especificaciones	0.51	x	
8	Levantar el molde con el carrito de montacarga	2.06	x	
9	Ubica y verifica que el molde esté en la posición correcta	0.37	x	
10	Colocar platos de la máquina sopladora	1.92	x	
11	Bajar el molde hasta los platos	2.87	x	
12	Sujetar con chuletas (perros, topes)	11.3	x	
13	Coloca mangueras de agua para refrigeración	2.86	x	
14	Verifica que todo este correcto	0.88	x	
15	Acoplamiento de portapi (sujeto a la manguera de aire)	1.02	x	
16	Preparación de la materia prima	4.53	x	
17	Formulación del color pedido	2.67	x	
18	Cierre de las puertas de la máquina	0.39	x	
19	Verificar que todo esté correcto	0.67	x	
20	Pesar el material	0.9	x	
21	Recojo del material en la tolva	17.16	x	
22	Verificar la temperatura adecuada para realizar el extrude	0.55	x	
23	Prender motores	0.9	x	
24	Regulación de espesor de manga	1.89	x	
25	Regulación de parados de soplado	1.02	x	
26	calibración de parizon	2.31	x	
27	Espera que la máquina termine el soplado	2.96	x	
28	Abrir el molde y extrae el producto	0.89	x	
29	Rebabar el producto	1.06	x	
30	Inspeccionar si el producto está en optimas condiciones	0.69	x	
31	Pesar el producto	0.4	x	
32	Verifica que todo esté correcto	1.09	x	
33	Coloca tapa y suncho al producto	0.38	x	
34	Enviar productos terminados al almacén	3.49	x	
35	Envía la materia reciclada al almacén de materia prima	0.7	x	
36	Registrar cuantos kilos de materia reciclada ha llegado	1.21	x	
37	Registrar la cantidad de kilos	1.99	x	
38	Programar el reprocesamiento	74.69	x	

FECHA:

OPERARIO:

EVALUADO POR:

Fig. 5 Standard work evaluation sheet

On the other greater knowledge of the subject, then, white cards are implemented, which will be used to classify elements that require maintenance (fig.6). In addition, forms are prepared to record the frequency of cleaning and to indicate sources of contamination and abnormalities.

ISSUE	SOLUTION

GLOVE S.A. CLEANING AND LUBRICATION PROGRAM

Machine:	Blower				
Prepared by:	Garrido Ricardo; Marquezado Katherine				
Date:	16/11/2021				
Rersión:	1				
Reviewed/approved:	José Marquezado Macharé				
Company					
Component	Activity	Frequency			
		Day	Week	Fortnight	My
Twelve	Internal cleaning	x			
	Check if the hopper does not have breaks		x		
	Check if the hopper has excessive plastic particles	x			
Body	External cleaning			x	
	Check if the machine has the necessary lubrication		x		
	Check for hose leaks				x
Doors	Check if the doors are with clean sheets	x			
	Check if the doors have correct oil		x		
Gear	Check for oxidation				x
	Check are sufficiently lubricated			x	
	Check if the nuts are loose		x		
Axis	Check if the shaft is in its correct position				x
	Clean the shaft				x
Remarks	This cleaning must be done before each day The machine must be turned off for internal cleaning Use cleaning EPPS correctly				

Fig. 6 PROBLEM AND SOLUTION FOR AUTONOMOUS MAINTENANCE

This will prevent breakdowns in the blowing machine, such as obstructions in the hopper or broken hoses due to excess dust. Finally, an increase in the hand, for the pilot validation of the TPM tool, training on autonomous maintenance is used so that the operators have MTBF indicator of 65.87 hours with respect to the initial value,which was 48.72, was achieved. Likewise, on the MTTR indicator, a reduction of 0.75 hours is obtained with respect to the initial 0.5 hours. Additionally, maintenance audits are used to analyze the impact of the tool, the current score is 88, and the OEE increased from 61.01% to 67.70% due to the increase in the availability indicator.

Secondly, the SMED tool is applied for the simulation method, in which the elimination and combination of internal and external activities is used; the resultobtained was 173.03 minutes with respect to the initial value of 204.98 minutes. Also, the SW tool is used, where activities thatdo not generate value to the processes are eliminated by means of 4 stages, then, training is implemented so that the operators do not perform the eliminated activities, thus, a value of 79.31 minutes is achieved, this means a reduction of 29.99 minutes, since the initial value was 109.3 minutes.

TABLE 1.
PROBLEM AND SOLUTION FOR AUTONOMOUS MAINTENANCE

Stages	N° of Activities			Activity Time (min)		
	Internal	External	Total	Internal	External	Total
Pre-implementation	27	13	40	166.51	38.47	204.98
Step 1	27	13	40	166.51	38.47	204.98
Step 2	20	20	40	116.61	86.33	202.94
Step 3	14	19	33	97.95	82.95	180.9
Step 4	14	13	27	93.65	70.47	164.12

Likewise, according to the contribution of the implemented model, the process of blowing the material and then cutting the scraps contained in thedrum is used. In this last process, the plastic scraps are accumulated and go through an evaluation where, being suitablematerial, they are crushed to reduce the size and finally they are taken to the blowing machine for a new manufacture. The resultof the simulation was a material recovery of 127.46 kg in a fullworking day, i.e. 36 additional drums were

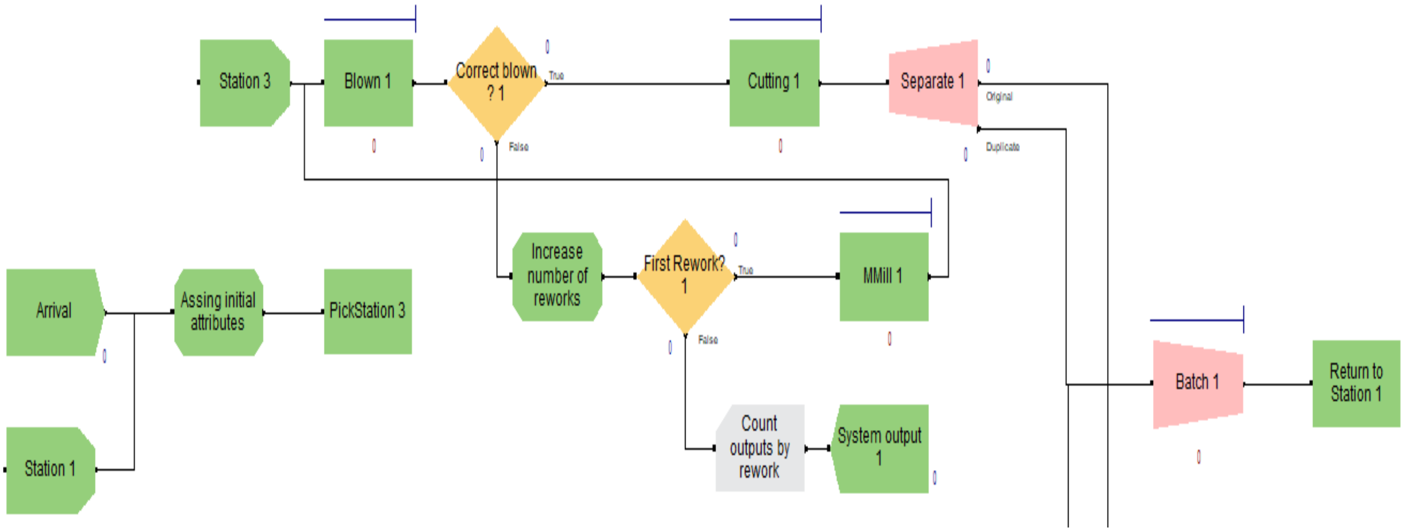

Fig. 7 Improved system rendering

produced.

Finally, it was possible to validate that the design of the Lean Manufacturing model through its 2 components (fig.6, TABLE 3), achieved the objective of an increase in the order fulfillment rate from 69.11% to 74.59%, which means that we are within the international standards established according to the literature review

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TABLE 2
COMPARISON BETWEEN THE CURRENT SITUATION AND THE IMPROVEMENT SITUATION

Components	Current Situation	Improved situation
Tsistema	6.773	5. 4079
TamCola BLOWER 3	2.7970	1.4194
TamCola BLOWER 4	2.5983	1.8201
TamCola BLOWER 5	2.2297	1.0765
TamCola BLOWER 2	2.7137	1.3964
TamCola BLOWER 1	3.3531	1.9271

V. DISCUSSION

5.1. Segmentation

To perform product segmentation, several scenarios have been selected. Through validation, different ways were applied to eradicate the problems identified for the blowing process for the drum family as the main product, since it presented the highest share of income and sales in the company. However, several types of products are presented that are necessary to compare with the application of the proposed model, this is distributed in drums (star product) in 34,638%, jabas in 33,549%, bottles in 27,806% and gallons 4.01% for this the following scenarios are made.

5.2. Scenario vs Result

5.2.1. Scenario 1:

Scenario1 is the monitoring of the process for the jabas family. For this family it begins with the selection of material, injected, extrusion, burr, weighing, cooling and screen printing where the jabas would already be ready for proper distribution. It is worth mentioning, that the main indicator OTD 75.22%, the activity time 91.47 minutes, TPM-OEE 71.30%, 5S-audits 88 and the mold change time 181.54 minutes. In addition, observing the processing time it takes to make the product shows that it is below the optimal time standards.

TABLE 3.
SCENARIO 1

Scenario 1 - Jabas	
Indicators	**Results**
On Time Delivery	75.22%
Activity time	91.47
TPM- OEE	71.30%
5S-Audits	88
Mold change time	181.54

5.2.2. Scenario 2

In scenario 2, it consists of evaluating the proposed model through the bottle blowing process. This process begins with the selection of the material, plasticized, blown, burred, weighed, cooled and screen-printed which allows you to have a more personalized presentation for the client. However, the main indicator OTD 69.43%, activity time 61.21 minutes, TPM-OEE 75.51%, 5S-audits 91 and mold change time 140.17 minutes. In addition, observing the processing time it takes to make the product shows that it is below the optimal time standards.

TABLE 4
SCENARIO 2

Scenario 2 - Bottles	
Indicators	**Results**
On Time Delivery	69.43%
Activity time	61.21
TPM- OEE	75.51%
5S-Audits	91
Mold change time	140.17

5.2.3. Scenario 3

In scenario 3, it consists of evaluating the proposed model through the blowing process for galloneras. This process begins with the selection of the material, plasticized, blown, burred, weighed, cooled and screen-printed which allows you to have a more personalized presentation for the client. However, that the main indicator OTD 82.16%, the time of activities 79.58 minutes, TPM-OEE 71.30%, 5S-audits 95 and the time of change of mold 129.38 minutes. In addition, observing the processing time it takes to make the product shows that it is below the optimal time standards.

TABLE 5
SCENARIO 3

Scenario 3 - Galoneras	
Indicators	**Results**
On Time Delivery	87.58%
Activity time	79.58
TPM- OEE	82.16%
5S-Audits	95
Mold change time	129.38

5.2.4. Results in potential scenarios

After having raised the other scenarios of jabas, jars and galoneras, the statistical evaluation is presented with the data that were raised to obtain the appropriate categories for each indicator of the research.

TABLE 6
POTENTIAL RESULTS OF OTHER SCENARIOS

DATA	Indicators				
	OTD	STANDARDIZATION	TPM-OEE	5S	SMED
Scenario	74.59%	79.31	67.70%	86	173.03%
Scenario	75.22%	91.47	71.30%	88	181.54%
Scenario	69.43%	61.21	75.51%	91	140.17%
Scenario	87.58%	79.58	82.16%	95	129.38%
Media	76.71%	77.89	74.17%	90	156.03%
Median	74.91%	79.45	73.41%	89.5	156.60%
Desv. East	7.70%	12.48	6.21%	3.91578	25.18%
Max	87.58%	91.47	82.16%	95	181.54%
n	4	4	4	4	4

5.3 Analysis of Results

Regarding what is mentioned in section IV, the validation of the model built through pilot and simulation was carried out, achieving the objective of increasing the order fulfillment rate. However, the economic and environmental factors must be analyzed, in this way, we can analyze the monetary benefits that the implementation of the model entails and the sustainability generated by the application of the model.

5.3.1. Economic Analysis

For the development of the economic evaluation of the project, a financial cash flow was prepared with an estimate of 12 months. It takes into account the costs that have been considered during the implementation of the improvement model and the benefit it gives to be applied through validation and simulation methods, achieving an increase in the benefit on plastic drums.

From the construction of cash flow, the financial indicators Net Present Value (NPV) and Internal Rate of Return (IRR) have been obtained, which are presented in Table 4. First, the NPV found is S/ 72,767, which means that the project is viable. On the other hand, with respect to the IRR found, a value of 103% is obtained, this value, when compared with the COK (10.5%), turns out to be higher, therefore, the project is profitable.

TABLE7
INDICATORS

Financial Indicator	Result	Interpretation
From	S/ 72,767	The project is viable and generates value
Shooting	103%	TIR > COK, the project is profitable

5.3.2 Environmental Analysis

In this section, the environmental analysis of the results found is presented. For the development, the 6R tool is used, which allows to identify those elements that can be evaluated and recovered through processes, this with the purpose of obtaining a new product and saving on the use of new material.

Under this approach, when blowing the material, the cutting process continues, where pieces of plastic are removed from the finished product, in this case the drum. These pieces are placed in bags and are moved to areas that are free, since they do not have a fixed location. When making a selection of the material, these pass to the mill and are reduced into smaller pieces that will later go to the hopper of the blowing machine to produce a new drum again, in this way, an improvement in the management of plastic waste and savings in new material is made. Additionally, through a matrix of Aspects and Impacts, this tool contributes to the elimination of soil pollution caused by the stacking of this material.

5.3.3 Future work

Once the research is finished, it is intended to expand knowledge through the analysis of other engineering impacts found during the development of the main problem, in this way, it contributes to the optimization of processes and quality for customers.

- Develop an improvement plan about the working conditions in the plastic plant. That is, to develop tables and chairs in order to avoid injuries during the operations used by the operators.
- Research about safety in the plastic industries, that is, analyze the activities through engineering tools the risks involved in each process applied by the operators and reduce the probability of accidents.
- Investigate the development of applied engineering tools in other industries through validation and pilot methods.

VI. CONCLUSIONS

The research project allows the improvement in the management of order fulfillment in the plastic sector using 5S, SW, SMED and TPM tools. Despite this, for future research, this model can be implemented for products that present a significant profit margin (Jabas, jars and Galoneras) and thus maintain continuous improvement.

The implemented model presented the combination of Lean Manufacturing tools with Lean Green applications specifically 6R and environmental impacts, so that they can increase the non-fulfillment of orders, each tool was validated through pilot and simulation in the Arena software, thus allowing great results to be obtained. It is important to note that the proposed model requires a large participation of senior management and operators.

The integration of Lean Manufacturing with 6R focused on themanufacturing processes of the plastics sector is able to increase order fulfillment by 74.59% by increasing the availability of the blow molding machines by 80.72%. Similarly, it was possible to minimize the time of the total activities of the process to 173.03 minutes, thus managing to recover a new product for every 30 rebabings, which represents 42% of the recovered material, highlighting the integration of the 5S in a positive way through the order and cleanliness of the blow molding area.

As a result, the main objective of the article was achieved by proving that the integration of the aforementioned tools and the added contribution perform a beneficial function for manufacturing companies that want to replicate the samemodel in order to obtain improvements in their production andsales.

Finally, by means of the realization of the investigation extra points have come out that should be involved in future investigations to construct a more powerful model with the purpose of increasing the percentage of efficiency and improvement in the processes, that is why, it is encouraged to make alignments to SMED and 6R with tests of CO2 emissions to the machines to obtain a more friendly plant with the environment, also it would be profitable that the combination of plant distribution is realized next to the tool 5'S to extend the order of the plant.

I. REFERENCES

[1] Sociedad Nacional De Industrias, “Reporte Sectorial N°04 - 2019,” Feb. 2019. Accessed: Apr. 13, 2021. [Online]. Available: https://www.sni.org.pe/wp-content/uploads/2019/07/Reporte-Sectorial-Plásticos_2019.pdf.

[2] G. Pinto, F. J. G. Silva, N. O. Fernandes, R. Casais, A. Baptista, and C. Carvalho, “Implementing a maintenance strategic plan using TPM methodology,” *Int. J. Ind. Eng. Manag.*, vol. 11, no. 3, pp. 192–204, Sep. 2020, doi: 10.24867/IJIEM-2020-3-264.

[3] M. Heydari, K. K. Lai, and X. Zhou, “Creating sustainable order fulfillment processes through managing the risk: Evidence from the disposable products industry,” *Sustain.*, vol. 12, no. 7, Apr. 2020, doi: 10.3390/SU12072871.

[4] K. Guillen, K. Umasi, G. Quispe, and C. Raymundo, “LEAN Model for Optimizing Plastic Bag Production in Small and Medium Sized Companies in the Plastics Sector,” *Int. J. Eng. Res. Technol.*, vol. 11, no. 11, pp. 1713–1734, 2018.

[5] Q. Liu and H. Yang, “An improved value stream mapping to prioritize lean optimization scenarios using simulation and multiple-attribute decision-making method,” *IEEE Access*, vol. 8, pp. 204914–204930, 2020, doi: 10.1109/ACCESS.2020.3037660.

[6] R. Sharma, “Overall equipment effectiveness measurement of TPM manager model machines in flexible manufacturing environment: A case study of automobile sector,” *Int. J. Product. Qual. Manag.*, vol. 26, no. 2, pp. 206–222, 2019, doi: 10.1504/IJPQM.2019.097767.

[7] A. M. H. Pereira, M. R. Silva, M. A. G. Domingues, and J. C. Sá, “Lean six sigma approach to improve the production process in the mould industry: A case study,” *Qual. Innov. Prosper.*, vol. 23, no. 3, pp. 103–121, 2019, doi: 10.12776/QIP.V23I3.1334.

[8] A. Muñoz-Villamizar, J. Santos, J. Montoya-Torres, and M. J. Alvaréz, “Improving effectiveness of parallel machine scheduling with earliness and tardiness costs: A case study,” *Int. J. Ind. Eng. Comput.*, vol. 10, no. 3, pp. 375–392, 2019, doi: 10.5267/j.ijiec.2019.2.001.

[9] R. Ahmad, M. Syazwan, and F. Soberi, “Changeover process improvement based on modified SMED method and other process improvement tools application: an improvement project of 5-axis CNC machine operation in advanced composite manufacturing industry,” *Int. J. Adv. Manuf. Technol.*, vol. 94, no. 1–4, pp. 433–450, 2018, doi: 10.1007/s00170-017-0827-7.

[10] R. S. Mor, A. Bhardwaj, S. Singh, and A. Sachdeva, “Productivity gains through standardization-of-work in a manufacturing company,” *J. Manuf. Technol. Manag.*, vol.

30, no. 6, pp. 899–919, 2019, doi: 10.1108/JMTM-07-2017-0151.

[11] R. Jayachitra and S. Parthasarathy, “A case study on productivity improvement in a display cases manufacturing industry,” *Int. J. Product. Qual. Manag.*, vol. 31, no. 2, pp. 151–166, 2020, doi: 10.1504/IJPQM.2020.110041.

[12] P. Ribeiro, J. C. Sá, L. P. Ferreira, F. J. G. Silva, M. T. Pereira, and G. Santos, “The impact of the application of lean tools for improvement of process in a plastic company: A case study,” *Procedia Manuf.*, vol. 38, no. 2019, pp. 765–775, 2019, doi: 10.1016/j.promfg.2020.01.104.

[13] S. Okwuobi *et al.*, “A reliability-centered maintenance study for an individual section-forming machine,” *Machines*, vol. 6, no. 4, 2018, doi: 10.3390/MACHINES6040050.

[14] J. Reyes, K. Alvarez, A. Martínez, and J. Guamán, “Total productive maintenance for the sewing process in footwear,” *J. Ind. Eng. Manag.*, vol. 11, no. 4, pp. 814–822, 2018, doi: 10.3926/JIEM.2644.

[15] I. M. Ribeiro, R. Godina, C. Pimentel, F. J. G. Silva, and J. C. O. Matias, “Implementing TPM supported by 5S to improve the availability of an automotive production line,” *Procedia Manuf.*, vol. 38, no. 2019, pp. 1574–1581, 2019, doi: 10.1016/j.promfg.2020.01.128.

[16] P. H. Tsarouhas, “Overall equipment effectiveness (OEE) evaluation for an automated ice cream production line: A case study,” *Int. J. Product. Perform. Manag.*, vol. 69, no. 5, pp. 1009–1032, 2019, doi: 10.1108/IJPPM-03-2019-0126.

[17] A. Muñoz-Villamizar, J. Santos, J. J. Garcia-Sabater, A. Lleo, and P. Grau, “Green value stream mapping approach to improving productivity and environmental performance,” *Int. J. Product. Perform. Manag.*, vol. 68, no. 3, pp. 608–625, Feb. 2019, doi: 10.1108/IJPPM-06-2018-0216.

[18] A. E. Bonilla Hernandez, T. Lu, T. Beno, C. Fredriksson, and I. S. Jawahir, “Process sustainability evaluation for manufacturing of a component with the 6R application,” *Procedia Manuf.*, vol. 33, pp. 546–553, 2019, doi: 10.1016/J.PROMFG.2019.04.068.

[19] R. D. Leme, A. O. Nunes, L. B. Message Costa, and D. A. L. Silva, “Creating value with less impact: Lean, green and eco-efficiency in a metalworking industry towards a cleaner production,” *J. Clean. Prod.*, vol. 196, pp. 517–534, Sep. 2018, doi: 10.1016/J.JCLEPRO.2018.06.064.

[20] M. S. Amjad, M. Z. Rafique, and M. A. Khan, “Leveraging Optimized and Cleaner Production through Industry 4.0,” *Sustain. Prod. Consum.*, vol. 26, pp. 859–871, Apr. 2021, doi: 10.1016/J.SPC.2021.01.001.