Improvement In The Production Process By Means Of The Six Sigma Methodology In The Ceramics Sector

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Article History: Received: 11 January 2021; Revised: 12 February 2021; Accepted: 27 March 2021; Published online: 10 May 2021

Abstract:
This paper allows to improve the processes of any company through the six-sigma methodology. This methodology is characterized by 5 stages: define the problem or defect, measure and collect data, analyze data, improve and control (DMAIC), this in order to reduce the rates of waste or excess in the ceramic sector of Cúcuta, Norte de Santander. In the ceramic sector there are different tools for quality control, where decision making is based according to production criteria, therefore it is a task that is often difficult to know which methodology can be more effective. Therefore, as a result of this study, the design of such methodology is identified, thus optimizing the use of statistical tools to determine, calculate, analyze and improve the production process of any company.

Key words: Improvement, logistics, six sigma methodology, production process.

Resumen: El presente artículo permite que a través de la metodología seis sigma se puedan mejorar los procesos de cualquier empresa. La metodología seis sigma se caracteriza por 5 etapas: definir el problema o el defecto, medir y recopilar datos, analizar datos, mejorar y controlar (DMAIC), esto con el fin de disminuir los índices de desperdicio o exceso en el sector cerámico de Cúcuta, Norte de Santander. En el sector cerámico existen diferentes herramientas para el control de la calidad, donde para la empresa, la toma de decisiones se basa de acuerdo a criterios productivos, por tanto, es una labor que suele complicarse en cuanto a cuál metodología puede ser más efectiva. Por tanto, como resultado de este, se identifica el diseño de dicha metodología optimizando el uso de herramientas estadísticas para determinar, calcular, analizar y mejorar el proceso productivo de cualquier empresa.
Palabras clave: *Mejora, logística, metodología seis sigma, proceso productivo.*

1. INTRODUCTION

The ceramic sector is currently one of the activities with high impact in the city of Cúcuta, Norte de Santander, where the importance of ceramics within the industry lies in its close link with the construction sector, providing products used in floor and wall coverings, as well as sanitary porcelain products. The ceramic sector in Colombia is highly concentrated; more than 80% of production belongs to four companies: ColCerámica S.A. (Grupo Corona), Cerámica Italia (10% of the country's flooring market), Alfagrés S.A. (national) and Eurocerámica (national). (national) and Eurocerámica (national). ***(CERAMICA, 2003).***

Therefore, this literature review aims to identify, evaluate and analyze the statistical tools used in the six-sigma methodology.

According to M.B. William, M.C. Adriana (2019) the application of tools to reduce the economic impact caused by monthly inventory adjustments, start from the basis of the DMAIC methodology supported in different lean manufacturing tools in order to diagnose the management system and identification of critical points to make improvements and evaluation of the impact on the operation to estimate the implementation costs with the improvements observed and their economic benefits.

Therefore, taking into account the above, it is of utmost importance to also consider the entire supply chain in the production process, since it is one of those that carries out the control, flow and efficient storage of the product. For this reason, making a good initial diagnosis in the production process will help the improvement and adaptation to the methodologies or statistical tools to achieve the best performance.

This paper consists of three stages. The first one contextualizes and describes the six-sigma methodology, the second one presents the methodology to carry out the structure of the production process and finally, the conclusions based on the methodology approach.

2. SIX SIGMA METHODOLOGY
(First stage)

It is a data-driven method for bringing Quality to near-perfection levels, different from other approaches in that it also corrects problems before they occur. More specifically, it is a disciplined effort to examine repetitive processes in companies ***(GestioPolis.com Expert, 2001).***

The goal of Six Sigma is to achieve processes with a quality, that is, processes that at most generate 3.4 defects per million opportunities. This goal is intended to be achieved through an improvement program, designed and driven by the top management of an organization, in which SS projects are developed throughout the organization with the objective of achieving improvements and eliminating defects and delays in products, processes and transactions. The methodology on which it is based is defined and based on statistical thinking and tools ***(J. M. Juran, 1998).***

Improvements in these areas represent significant cost savings, opportunities to retain customers, capture new markets and build a reputation as a company of excellence.

Six Sigma can be defined as:(i) a statistical measure of the level of performance of a process or product, (ii) a goal of achieving near perfection through performance improvement, and (iii) a management system to achieve lasting business leadership and world-class performance in a global environment.

Therefore, the DMAMC methodology is focused on production processes, seeking to meet customer requirements in terms of quality, time and service so that the finished product is the one they expect, i.e., with zero defects, contributing to the growth of the economy in northern Santander.

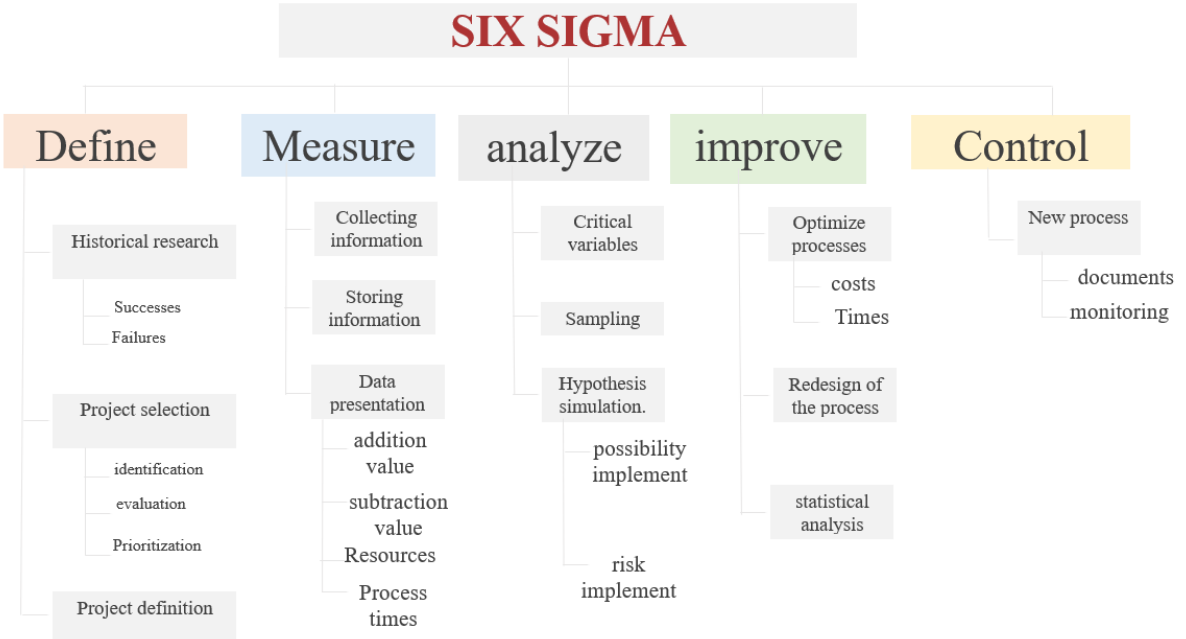

Figure 1: Six Sigma Methodology - DMAMC or DMAIC Methodology
Source: GestioPolis.com Expert, 2001.

2.1 Definition Phase: potential Six Sigma projects are identified, and must be evaluated by management to avoid underutilization of resources. Once the project is selected, its mission is prepared and the most adequate team for the project is selected, assigning it the necessary priority ***(GestioPolis.com Expert, 2001).***

2.2 Measurement Phase: consists of the characterization of the process by identifying the key customer requirements, the key product characteristics (or result variables) and the parameters (input variables) that affect the performance of the process and the key characteristics or variables. From this characterization, the measurement system is defined and the process capability is measured ***(GestioPolis.com Expert, 2001).***

2.3 Analysis Phase: Current and historical results data are analyzed. Hypotheses about possible cause-effect relationships are developed and tested using relevant statistical tools. In this way, the team confirms the process determinants, i.e., the key input variables or "vital few" that affect the process response variables ***(GestioPolis.com Expert, 2001).***

2.4 Improvement Phase: determine the cause-effect relationship (mathematical relationship between the input variables and the response variable of interest) to predict, improve and optimize the operation of the process. Finally, the operational range of the process parameters or input variables is determined ***(GestioPolis.com Expert, 2001).***

2.5 Control Phase: consists of designing and documenting the necessary controls to ensure that what has been achieved through the Six Sigma project is maintained once the changes have been implemented. When the objectives are achieved and the mission is finished, the team informs the management and dissolves ***(GestioPolis.com Expert, 2001).***

In fact, the conjugation of all the phases of the six-sigma methodology allows the development of continuous process improvement, focusing on reducing and eliminating defects or failures in the processes.

2.1. STATE OF THE ART

Table 1: State of the art by author, date, year, project title, methodology and contributions made.

AUTHOR DATE AND YEAR TITLE	**METHODOLOGY**
José Ramón Vilana Arto 2010-2011 Supply Chain Management Operations Management Supply Chain Management.	Supply Chain
CONTRIBUTIONS	
This document describes the management of the supply chain, which encompasses all activities associated with the flow and transformation of goods and associated information from the raw materials stage to the end user. It is essentially a set of connected suppliers and customers; where each customer is in turn a supplier to the next organization "downstream" until the finished product reaches the end user. This allows to provide a new approach to develop strategies for companies **(Arto 2011).**	

Mantilla Celis, Olga Lucía Sánchez García, José Manuel August 10, 2012. Technological model for the development of logistics projects using Lean Six Sigma.	Lean six-sigma
CONTRIBUTIONS	
This paper describes a model proposed by the authors, whose purpose is to guide companies in improving their logistics performance, analyzed from the perspective of increasing the level of service and reducing costs. For this, supply chain, logistics, lean manufacturing, six sigma and lean six sigma concepts were used. The methodology proposed for the development of the model is DMAIC (Define, Measure, Analyze, Improve and Control), supported by several tools selected for each phase of the model, leading to the elimination of waste in flows and operations, reduction of delivery time, reduction of variation in processes and increase in value. Therefore, thanks to the contributions of each of the mentioned authors, the methodology to be developed is strengthened because it is applicable to the logistic improvement of any company. **(Mantilla Celis and Sánchez García 2012).**	
R.A. Gomez, P.D. Medina, A.A. Correa. November 30, 2012 Six Sigma in the Supply Chain.	Six Sigma.
CONTRIBUTIONS	
This paper identifies papers published from 2000 to 2010 regarding the use of the six-sigma methodology in the supply chain. The purpose of this is to contribute to the design and improvement of supply chains in logistics systems in a generic way. It also provides the opportunity to use the design of experiments and other statistical techniques to design or improve efficient processes **(Gómez, Medina, and Correa 2012).**	
Felizzola, Heriberto Carmenza, Jimenez Amaya, Luna February 2014 Lean Six Sigma in small and medium-sized enterprises: a methodological approach.	Lean six-sigma
CONTRIBUTIONS	
This paper presents that Six Sigma and Lean Manufacturing are approaches to quality and productivity improvement that have been implemented with great success in large companies worldwide, in the field of manufacturing and services. Therefore, this paper proposes a methodology for the implementation of an integrated approach, commonly called Lean Six Sigma (LSS), which is adapted to the needs and characteristics of SMEs. Accordingly, this methodology provides significant savings in costs of poor quality, decreases in product returns, in addition to achieving the implementation of good practices in process management	

(Felizzola, Carmenza, and Amaya 2014).

Becerra, Yeimy Liseth. September 2014 Methodological proposal for the definition of improvement strategies in SME logistics.	DMAIC, Logistics.

CONTRIBUTIONS

The project belongs to the realization of the last stage of the base project of Methodological design on storage logistics, acquisition, appropriation of information and communication systems for Colombian SMEs, bakery subsector.

To this end, a review was made of the methodology used during the execution of the base project, as well as the state of the art of the techniques used in similar research for the evaluation and definition of improvement strategies in SME logistics. According to this, the techniques reviewed were compared and a methodological proposal was configured, composed of the techniques that represented the greatest advantages for the development of the research.

Where the methodological proposal for the definition of improvement strategies in SME logistics, based on the elements that were most appropriate according to the analysis carried out, The methodological proposal was framed in the phases of the DMAIC tool (define, measure, analyze, improve and control) defining each of the activities in each phase.

They were based on this tool in order to facilitate the management and inclusion of elements of the supply chain, for the logistics improvement of the productive sector **(Becerra 2014).**

Alexander Bohigues Ortiz. September 2015. Development and implementation of a Six Sigma model for quality and productivity improvement in industrial SMEs.	Six Sigma.

CONTRIBUTIONS

In this research project, a review of the six-sigma methodology is made, where the steps of this methodology for the implementation in a company of any sector are explained.

Therefore, the six sigma methodology is about a change in the mentality of each and every one of the people that make up any organization. **(Bohigues Ortiz 2015).**

C.R.Yesenia, Mayra, R.R.Alexandra, Johanna 2016 Development of the lean six sigma methodology in the SME JC Muebles in the city of Bogota, Colombia.	Lean six-sigma

CONTRIBUTIONS	
This project is based on the improvement of quality and reduction of reprocessing in the production area of the furniture company JC in the city of Bogota DC. It is based on the lean six sigma methodology according to the objectives of the company focused on internal returns in the painting area, because they have a negative impact on their profits in the previous three years. Likewise, reprocesses were identified, as well as the use of tools for decision making and design for their respective validation **(C.R. Yesenia and R.R.Alexandra 2016).**	
Orjuela-Castro, Javier Arturo Suárez-Camelo, Norberto Chinchilla-Ospina, Yamit Israel. December 2016 Logistics costs and methodologies for supply chain costing: a literature review.	Operation of logistics systems.
CONTRIBUTIONS	
This paper presents a literature review on supply chain (SC) costing methodologies, with emphasis on logistics costs. By outlining an analytical perspective, it evaluates the different methodologies for measuring SC and logistics performance. It also establishes in which link it is applied, whether to the entire CS or to the company. After determining a taxonomy, it sets out in detail the costs and processes applied by the different authors, and also examines the fundamental differences between the methodologies. It finds the need to develop its own methodology to determine the costs of means and mode logistics in CS. Therefore, it allows to identify the costs of logistics processes, performance measurements and base methodologies to obtain an effective and profitable development for any company. **(Orjuela-Castro, Suárez-Camelo, and Chinchilla-Ospina 2016).**	
Alejandro, Daniel Argoti, Egas 2017 Waste reduction project in the production process of the generating machines at the Proquinal S.A. Colombia plant using the DMAIC methodology.	DMAIC.
CONTRIBUTIONS	
This project is based on improving its processes and eliminating waste due to the high operating costs they represent (production time, reprocesses, raw materials, inputs), which is the epicenter of this work. In this way, the DMAIC tool of the Six Sigma philosophy is used, which, by means of systematic steps, allows a diagnosis of the process problems and the application of statistical tools in order to identify the causes that have the greatest impact on the problem. Therefore, the six sigma philosophy contributes to the improvement of production processes and to	

mitigate and direct the production processes towards continuous improvement **(Alejandro and Argoti 2017).**	
Cayetano Llacsa, Oscar Jesús. May 2018 Proposal to improve the logistics process of a construction company.	DMAIC, Kanban, JIT and 5S.
CONTRIBUTIONS	
This research proposal is based on a new model of the logistics process of a construction company reducing waste using the tools of the Lean philosophy, with the objective of standardizing processes and achieving customer satisfaction at the time of delivery, as well as increasing the productivity of the company by reducing the time of delivery delay due to different causes. It starts using the DMAIC methodology, for an orderly process of implementation of methodologies and selection of tools. Likewise, the JIT tool is used through its Kanban and Pull System tools to reduce waste, costs, inventories of raw materials and finished products and finally the 5S methodology has as its main objective the improvement in the processes in terms of quality and productivity, industrial safety and work environment, obtaining quick results and with a low implementation cost, all these methodologies in order to be able to solve the problem in the construction company **(Cayetano Llacsa 2018).**	
M.B. William Camilo, M.C. Adriana Stephany .2019 Application of lean tools for the improvement of the operational management system of the distribution center of almacenes corona s.a.s located in Cali.	DMAIC.
CONTRIBUTIONS	
This project performs the application of lean tools to reduce the economic impact caused by monthly inventory adjustments. It starts from the basis of the DMAIC methodology supported by different lean manufacturing tools; this in order to diagnose the management system and identification of critical points to make improvements and evaluation of the impact on the operation to estimate the implementation costs with the observed improvements and their economic benefits **(M.B. William Camilo 2019).**	

Source: Own elaboration.

3.METHODOLOGY TO BE APPLIED
(Second stage)

It focuses on a quantitative research:

Exploratory study: visits to the selected company; this method allows, through the information obtained during the observations and tests, to make a diagnosis of the current situation of the manufacturing process in its supply chain.

Descriptive Study: description of the identification of the current situation of the producing company to reduce defects in its products.

The following stages are proposed:

3.1 Stage I: Theoretical foundations of the supply chain and the six-sigma methodology.

In this stage, all the information related to the supply chain and the six-sigma methodology is compiled, starting with its definitions, its impacts and ending with its effects, in order to reflect all the factors that influence the ceramic sector.

3.2. Stage II: Sampling of the production process.

For this stage, it is expected to investigate the critical points that occur in the supply chain of the production process through an exploratory study that allows, through observations and tests, to obtain the corresponding statistical information in order to make a diagnosis of the process of making ceramics; then a descriptive method that allows to discover where the process should improve to evaluate the results obtained in the development of the project.

3.3. Stage III: Validation of the improvement model using the Six Sigma Methodology.

According to the information obtained in stage II, a statistical analysis is carried out according to the samples collected. This will be based on a statistical analysis, description of trends, comparison of samples, relation of variables and a comparison of results. The purpose of this is to define the improvements of the most recommendable model for the productive process by developing the phases of the six-sigma methodology.

3.2. Stage IV: Model Evaluation

According to the results obtained, an evaluation and review of the improvement model will be carried out in order to observe the changes that were generated according to the proposed methodology, in order to make comparisons with what was initially observed and what will be
obtained with the six-sigma methodology.

Image 1: Six sigma.
Source: Inspecciondealimentos.files.wordpress.com. 2010. Six sigma. [online] Available at: <https://inspecciondealimentos
.files.wordpress.com/2010/11/6sigma.jpg>
[Accessed 10 November 2010].

6-sigma is equivalent to zero defects. It is a level of 99.9997 percent correct operation; where defects in processes and products are practically non-existent.

6-sigma is 3.4 defects per million
6-sigma is 0.34 defects per 100 thousand.
6-sigma is 0.003 defects per 10 thousand.
6-sigma is 0.00034 defects per thousand
6-sigma is 0.00034 defects per 100

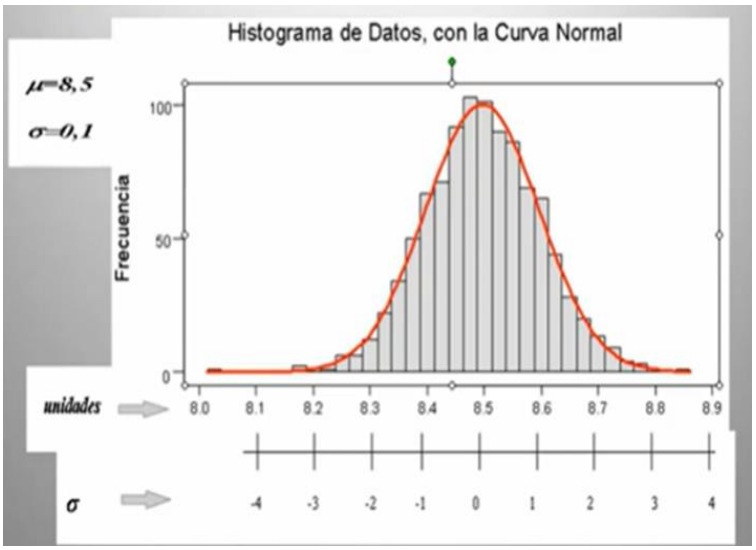

Figure 2: Histogram of data,
Source: YouTube.com. 2020. Before you continue to YouTube. [online]. Original version in Spanish language
Available at:
<https://www.youtube.com/watch?v=Ue1NskecBJ8> [Accessed 11 February 2020].

Six-sigma is a measure of variability. It indicates that the information that falls within customer requirements, the greater the sigma of the process, the greater the process outputs, products and services that meet customer requirements.

The **6-**sigma quality level corresponds to 3.4 defects per million observations. It is considered an excellent quality level and, therefore, a strategic objective to be achieved by a company aiming at customer satisfaction.

4. JUSTIFICATION

The noun "cycle", which precedes DMAIC, is important. Certainly improvement, within the Six Sigma context, is interpreted as a cycle and not as a punctual activity that, performed once, is enough to achieve the desired objective (Corcoba 2012).

The famous Deming cycle, also known as PDCA cycle (Aguilera, 2002), immediately comes to mind for anyone who has had any relation with process improvement issues. Certainly, the PDCA cycle is a remote antecedent of the DMAIC, but the latter surpasses it in an unquestionable way (Corcoba 2012, Saghafi et al 2021).

"Plan" and "Do" are naturally the WHAT to do? The question is HOW to do it? This is the neuralgic point that marks the essential difference between Six Sigma and any other improvement method before it. Six Sigma not only says what to do, but, and this is what is really important, it says how to do it (Corcoba 2012).

Deming, with a fine vision, already spoke of the need for a permanent improvement cycle; in the case of Six Sigma the situation is even clearer. In practice, to speak of Six Sigma means that a process has a level of quality such that in the short term only 3.4 defects per million opportunities occur. This figure implies a drastic change in the way of thinking about processes because, in fact, it assumes that they are free of defects: the old objective of "zero errors" made reality. No one would expect, then, that it would be possible to bring a conventional process - with, say, one percent defects - to a Six Sigma level from a single improvement project (Corcoba 2012).

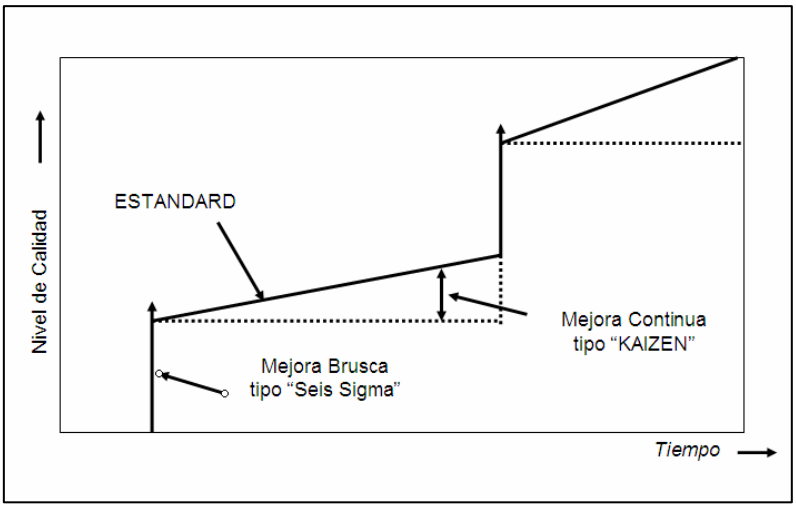

Figure 3: Continuous improvement and Six Sigma improvement.
Source: Continuous improvement and Six Sigma improvement. (Corcoba 2012). Original version in Spanish language

5. MONITORING MEASUREMENT PARAMETERS

Table 2: Measurement parameters for monitoring the production process.

MEASUREMENT / MONITORING PARAMETERS			
OBJECTIVE	**FORMULA**	**GOAL**	**FREQUENCY**
Manufacture products according to specifications	$\frac{Reports\ of\ non\ conforming\ treated\ products}{\#\ of\ non\ conforming\ products\ reported}$	>= 90%	Monthly
INDICATOR	**FORMULATE**	**GOAL**	**FREQUENCY**
Compliance with the production program	$\frac{n°\ of\ activities\ performed}{n°\ of\ activities\ programmed} x100$	>= 80%	Monthly
Waste in the drying process	$\frac{waste\ presented}{total\ product\ finished} x100$	<=5%	Monthly
Conforming product	$\frac{total\ conforming\ product}{total\ cooked\ products} x100$	>= 85%	Monthly

Source: Tejar Arcillas del Rosario.

One of the main objectives of the company Tejar Arcillas del Rosario is the elaboration of products according to its specifications, therefore it is considered that the goal to achieve this objective must be >= 90% monthly, which means that each product elaborated must have the best quality standards for the customers.
Likewise, there is a waste indicator in the drying process of >=5% per month, which indicates that it is a good indicator, because what is sought is to have the least possible waste in the products in order to achieve a compliant product with zero defects.

6. CONCLUSIONS

(Third stage)

The six-sigma methodology offers opportunities for any company that wishes to improve its production process, since it is based on constant improvement and the fulfillment of the customer's needs.

By using the six-sigma methodology, it is possible to identify the causes of all the waste in any production process, with the purpose of achieving the reduction of each one of the errors or failures in any company.

The training of personnel and the proper use of each machinery are essential in any organization; therefore, it is of utmost importance that this type of actions can be carried out so that both workers and employers are hand in hand with each of the processes.

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