Stencil control in the automatic insertion of a PIM Company.

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Abstract

The article evaluated the control of Stencil in the subprocess of Printing of the SMD line of a company located in the Industrial Pole of Manaus (PIM), to provide subsidies to develop a computerized system. With computerization, the focus of employees will be directed to the activities of production and quality of manufactured products, also, the collection of process data, done in real-time, will allow managers to better monitor and take actions in the process. To this end, a case study, bibliographic research of articles, dissertations, and theses involving the theme, and documentary research (forms, records, etc.) with the sectors involved were used. The descriptive statistics method was applied, quality tools were used, aimed at identifying and solving problems such as PDCA, Pareto, Ishikawa Diagram, flow chart, and 5W2H. A study of the activities related to the control of the Stencil was carried out, of the documentation used in the process, as well as of the factors and causes related to the effective Stencil control. Among the results, 24 causes affect the performance of the Stencil control, concluding that the main failures were human, due to the prioritization of production goals by the employees, leaving the other activities in the background, which is why the 24 guidelines proposed for the computerization of this process become relevant, some of which are: defining means to identify each Stencil using a bar code or QR code; do not allow the use of the Stencil if one of the activities unfinished in the process; stop production when an activity is not performed; digitize the documents used in this process; create an automatic notification to those responsible, when an action is necessary, etc.

Keywords: Automatic insertion; Stencil control; Quality tools

1. Introduction

This case study was carried out at Company X, installed since 1994 at the PIM (Industrial pole of Manaus) with 1,400 employees, of whom 1,260 (90%) work with the assembly of printed circuit boards for electronic products, such as microwaves, notebook chargers, voltage converters, remote controls and digital routers, a product line considered the organization's flagship (80% of its 2018 revenue).

Its manufacture has 20 lines of manual insertion (IM), 24 lines of automatic insertion of assembly (IA)

SMD (Surface Mount Devices), 12 automatic insertion machines PTH (Pin Through Hole), and a training area and a laboratory of trials.

This research focused on the automatic insertion (AI) process, specifically in the assembly of ultra miniaturized components for surface mounting (SMD), since the company has invested in the last 5 years to automate and computerize the production steps without yet completing the implementation at over time.

Some of the equipment (Figure 1) of an AI assembly production line are: 3 - Printer: applies solder paste or adhesive to plates; 4 - SPI (Solder Paste Inspection): inspects the solder paste or adhesive applied to the plate; 6 - Pick and Place - Chip Shooter: assembles smaller and simpler components (resistors, capacitors, etc.); 7 - Pick and Place - Fine Pitch: assembles larger components such as integrated circuits, connectors, shielding, etc. (SILVA, 2015).
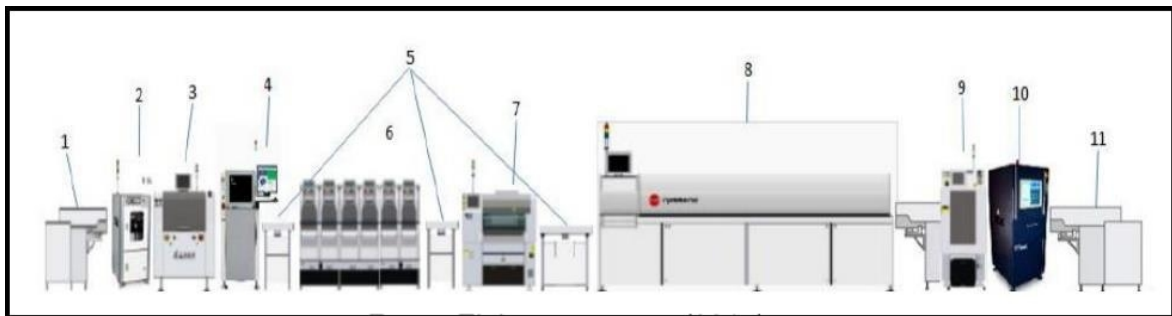
Figure 1: Standard line of automatic insertion

Source: Silva (2015)

Besides, Company X's SMD assembly line process can assemble 2.8 million components/hour and is comprised of the following sub-processes: Printing, Component Assembly, and Fusion.
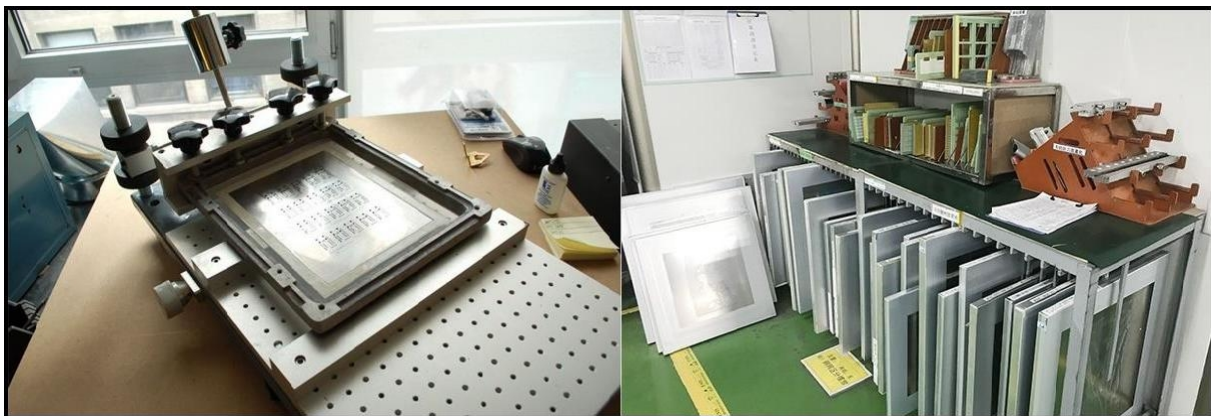
Figures 2 and 3: Examples of Stencils

Source: Venture Electronics <https://www.venture-mfg.com/pcb-stencil/>

In printing, the solder paste is deposited utilizing the Printer (component 3 of Figure 1), in addition to a screen known as Stencil (Figures 2 and 3). Also, Stencil, solder paste, and Printer parameters are controlled, since they are essential to maintain the quality of manufactured plates.

The Stencil transfers a precise amount of solder paste in the correct positions of the Printed Circuit

Board (PCB) and its control is relevant, carried out through the assessment on the receipt; evaluation during the process; disposal assessment; proper handling; analysis of useful life; revalidation of useful life; cleaning; and also by measuring the surface tension at a predetermined frequency.

Concerning Component Assembly, this subprocess uses Pick and Place machines (equipment 6 and 7 in Figure 1) to assemble all electronic components on the plates, according to the product structure defined by engineering. Finally, Fusion is the sub-process that fuses the solder paste deposited on the plates, with mechanical fixation and electrical connection between the components.

At Company X, control of the Stencil has been carried out manually by employees and recorded on forms, causing numerous problems due to the omission of procedures and records due to operational failure, such as lost forms, wrong sums, no data entries, an entry in the wrong form, erasure of data, torn forms, among others.

The Company has invested in the computerization of production processes, including AI, to a) manage production information in real-time; b) improve traceability; c) issue notices and reports to improve the effectiveness of the actions; d) avoid failures; e) better meet customer requirements.

As a result, developers need information and experience from employees in the Production, Engineering, Information Technology, and Quality sectors so that they can deliver solutions that help reduce the number of problems detected in the Printing subprocess, the target of the research.

A study in the AI line process carried out between May and September 2019 (Figure 4) revealed that 1,181 defects (Número de Problemas) occurred, with the majority (436 occurrences or 36.92%) being in the Printing (Printagem) subprocess. After evaluating the defects presented in this subprocess, the majority (330 occurrences or 75.68%) of the problems are located in the control of the Stencil (Figure 5).
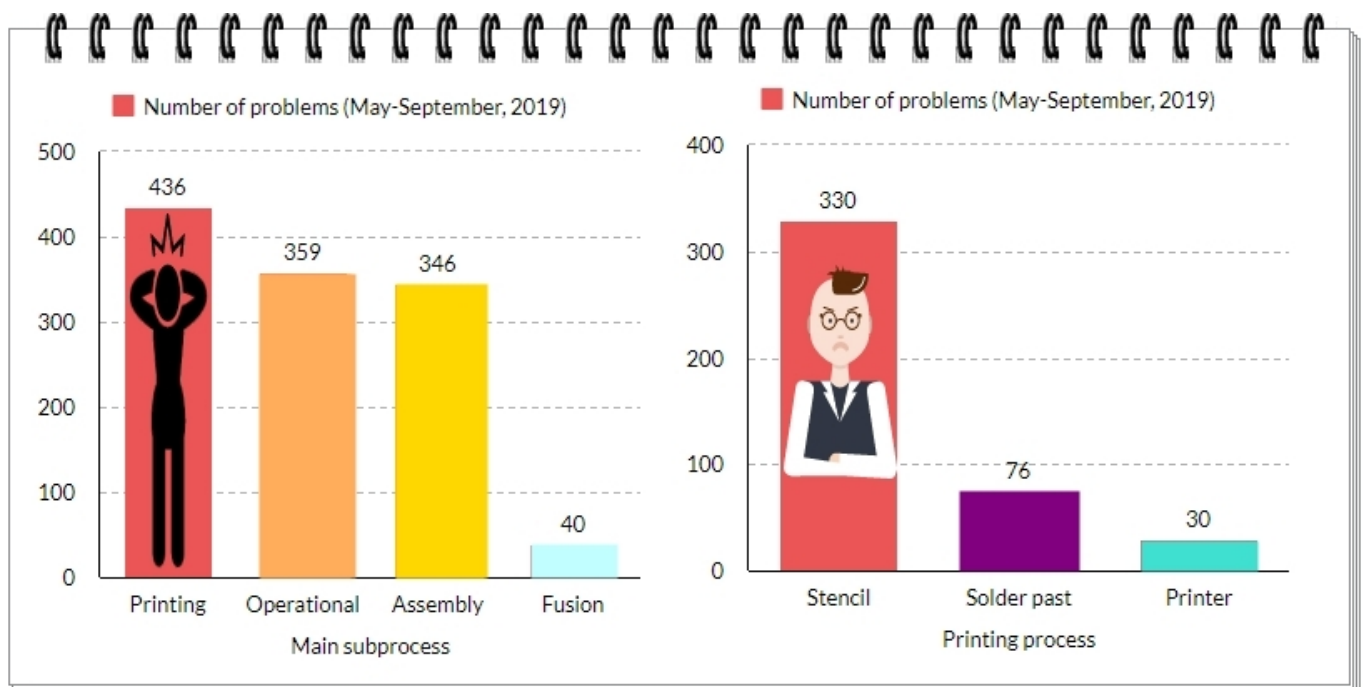

Figure 4: Number of defects in the sub-process   Figure 5: Number of defects in the Printing
              Source: Company X   Source: Company X

1.1 Question and Objectives

The question that motivated the research is "how to provide developers with useful information that contribute to the effectiveness of the computerization of the Stencil control?"

The general objective is to provide subsidies for the development of a computerized system for thecontrol of the Stencil in the subprocess of Printing of the SMD line of Company X.

The specific objectives were:

a) to map the main activities of the control of the Stencil;

b) map the instructions and documentation for the control of the Stencil;

c) identify the critical factors of a sub-printing process, aiming at an effective control of the stencil;

d) to identify the main problems existing in the control of the Stencil, as well as its causes;

e) propose guidelines to make the control of the Stencil more efficient, based on the computerization of this process.

1.2 Importance of research

In Brazil, this theme is in sub-area 1.3 (Maintenance Management) of the Industrial Operations and Processes Engineering area, linked to Industrial Engineering. Despite its relevance, there is some difficulty in finding articles in journals or similar events of Industrial Engineering in Brazil, as well as in some thesis database in the country (Table 1).

Table 1- Search for "Stencil Control in Automatic Insertion" in events/journals, and database of thesis on Industrial Eng.

SOURCES	QUANTITY	AUTHORS
ENEGEP Annals (1996 to 2018)	1	Conceição et al., (2009)
On Line Journal (ISSN16761901)	0	0
GEPROS Journal (ISSN19842430)	0	0
Management & Production Journal (ISSN0104530X)	0	0
Bank of Dissertations and Theses - USP	0	0
Bank of Dissertations and Theses - UFRJ	0	0
Bank of Dissertations and Theses - UFRS	0	0
Bank of Dissertations and Theses - UFPA	1	Uhlmann (2015)
Bank of Dissertations and Theses - UFAM	1	Bitar (2015)
Bank of Dissertations and Theses - UFSC	1	Doro (2004)
Total	4	-

Source: Author

A general search on the Internet found articles, dissertations, or theses, but mostly international, in English (FLECK, 2003; HUANG et al., 2011; TSAI, 2007; TSAI, 2008; KHADER; YOON; LI, 2017; ANGLIN, 2009; SEZGIN et al., 2017; HE; EKERE; CURRIE, 1998; BARAJAS et al., 2008); GOPAL et *al*., 2007). Thus, the study acquires more importance for Industrial Engineering, as it contributes to the academy to reflect on a little-explored theme in a region with an Industrial Pole with hundreds of companies that use automatic insertion in their manufacturing processes.

For Company X, it will be possible to broaden the view of the importance of the problem, since it is widely recognized that 60% of the welding defects that occur during the assembly of PCB, are associated with the Stencil Printing subprocess (TSAI, 2008; HE et al, 1998; PAN, 2001). Also, this study contributes to creating a culture of combating waste, since in automatic insertion lines about 40% of production time may be being wasted due to problems related to improper application of Printing (KHADER; YOON; LI, 2017).

The research contributes to the preventive and evaluative process of the quality of the organization, as there is a study that points out that every dollar spent on prevention and quality assessment, one can earn 4 dollars in the reduction of internal and 32 external failures (HELDT, 1994).

The investigation of the Stencil control process, considering that information is the essence of Quality, brings valuable knowledge about the data collected during the manufacturing processes that are crucial for analyzing the problems and their possible causes (MOURA, 1996). So, knowing that the use of information is fundamental to obtain data in real-time, information technology proves to be a relevant tool for the organization to remain competitive in the market (FREITAS, 1997; STONER, 1999).

2. Theoretical Reference

2.1 SMT (Surface Mount Technology)

In the SMT, the electronics components are assembled on the surface of a PCB (Figure 6), while in the technology that preceded the SMT, known as PTH, the components are assembled through holes in the PCB (Figure 7).
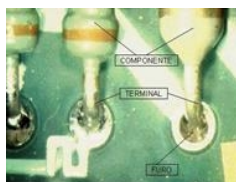
Figure 6: SMD Component   Figure 7: PTH Component
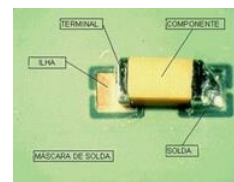
Source: DSTOOLS <https://dstools.com.br/introducao-a-tecnologia-smd/>

Moraes (2006) comments that the technological advances made possible the use of equipment, techniques, and products that influenced the automation of productive processes in the industries, making possible the progress in the levels of precision, flexibility, and capacity to perform large volumes of production. Fuse (2019), on the other hand, believes that in SMT, the components are welded on the surface of the plate, not requiring the plate to be perforated.

This technology emerged in the mid-1960s and is still evolving. Initially, the components were produced in packages similar to PTH components, where the terminals were cut and shaped to allow welding on the surface of the plate, with the width of the terminals and the geometry of the components being continuously reduced.

In SMT technology, Pick and Place component insertion machines (Chip Shooter and Fine Pitch) are used throughout the production process, from the application of the solder paste to the assembly of the components, and remelting of the solder paste. As the components in general, they are small, sensitive, and require an assembly precision, requiring strict control of the process parameters (MORAES, 2006).

Finally, it is worth noting that the manufacture of a PCB involves the selection of components, the layout of the board, and the manufacturing, assembly, and testing processes. During these steps, various defects can occur. Understanding the origin and consequences of defects is essential for corrective and preventive actions to be taken (DORO, 2004).

2.2 The printing

In this sub-process the solder paste or adhesive is deposited on the PCB, using the Printer.

A Stencil has also used that changes according to the product to be produced. To guarantee a good deposition of the solder paste, it is necessary to control some parameters of the Printer such as a) printing speed; b) squeegee pressure; c) Stencil separation distance from the printed circuit board; d) speed of separation of the Stencil and the printed circuit board; e) squeegee size; f) type of squeegee; g) cleaning frequency.

The parameters must be documented so that they can be checked by the machine operators before starting the production process. It is recommended that the parameters appear on the Quality Control (QC) checklist for verification at a specified periodicity and to ensure greater control of the process. Their change must be recorded in an action plan prepared by the team involved to standardize and disseminate learning and continuous process improvement.

2.3 Stencil

It is a metalized screen with openings (Figure 8) according to the PCB drawing (Figure 9), whose function is to ensure proper deposition in the solder paste on the printed circuit board, contributing to the quality of the components' weldability in the PCB.

Figure 8: Openings in Stencil   Figure 9: PCB without component-PAD'S.
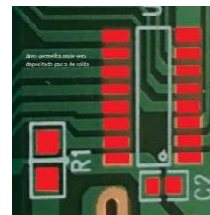
Source: Author

In the making of the Stencil, the chemical machining, electroforming or laser process is used, and it is necessary to send the following information to the manufacturer: a) image photolith, or Gerber or PCB file without assembly; b) dimensional specifications of the pads/holes (if necessary); c) type of metal, thickness, and type of fiducial; d) dimensional of the Stencil and frame; e) relative position of the image on the Stencil; f) other complementary information.

To ensure the quality of the solder paste deposition and to control the Stencil during the PCB assembly process, the following activities are carried out:

a) evaluate the received stencils;

b) identify received Stencil;

c) perform cleaning of the Stencil;

d) control the amount of printing performed (useful life);

e) revalidate Stencil when necessary;

f) perform a surface tension test;

g) discard Stencil with problems;

h) evaluation of the Stencil during the process.

These activities are recorded on forms by employees to improve process control and, through changes in control parameters, the results obtained for continuous process improvement can be evaluated.

2.4 Quality Tools

It is not news that much has been written about quality. For Juran, "Quality is the absence of defects", it is "suitability for use". Crosby, on the other hand, believes that "Quality is the product's compliance with specifications". Deming says "Quality is everything that improves the product from the customer's point of view". In Ishikawa's view, "Quality is developing, designing, producing and marketing a quality product that is economical, more useful and always satisfying to the customer". For Feigenbaum, "Quality is the correction of problems and their causes throughout the whole series of related factors such as marketing, projects, engineering, production, etc., which influence user satisfaction" (FREITAS, 2009).

Quality tools are means that define how to collect, analyze, and propose actions to improve processes (CAMPOS, 2013). To obtain better results, all employees of the organization must know and make use of the following basic quality tools: a) PDCA cycle; b) histogram; c) Pareto diagram; d) Ishikawa diagram; e) control chart; f) process flow chart; g) dispersion diagram; h) verification sheet; i) brainstorming, etc.

For this article, only the PDCA Cycle, Pareto Diagram, Ishikawa Diagram, and Flowchart tools will be addressed, as they will be used in the study.

2.4.1 Organizational Learning Cycle PDCA (Plan, Do, Check e Action)

The PDCA cycle (Figure 10) is one of the most used and well-known management tools for improving processes and solving problems (WERKEMA, 1995).

Figure 10: PDCA Cycle

Source: Siteware <https://www.siteware.com.br/en>

The first step is to plan, which consists of identifying the problem, finding out where and why it started, identifying and prioritizing solutions, as well as developing an action plan.

The second step is to carry out the actions, involving people, including the education and training process.

The third step is to check the actions to verify that they were carried out as planned.

Finally, the fourth step is intended to act, which can take two forms:

a) the first is to standardize the actions that have had good results, as well as to disseminate them;

b) in case of errors or non-conformities, the action is to reflect on the causes of these errors and correct them through corrective actions, pointing out guidelines so that the problem does not recur.

2.4.2 Pareto Diagram

The Pareto Diagram identifies the factors responsible for most of the problems, facilitates the visualization and identification of the most relevant causes or problems, thus guiding organizations to focus their actions on the identified issues.

The Pareto Principle - also known as the 80/20 rule - follows the observations of economist Vilfredo Pareto, whose studies show that 80% of the land in Italy belonged to 20% of the population.

Juran realized that this same 80/20 rule could also be applied to quality issues: he coined the phrase "the vital few and the trivial many" to convey that a small percentage of main causes can result in a high percentage of problems or defects. ("History of Dr. Juran | Juran", [s.d.])

In Quality Control, Pareto identifies the factors responsible for the greatest effects in terms of tailings, scrap, or costs, and this information is used to drive process improvement.

Figure 11 shows the elements (Frequency, Causes, Accumulated frequency) of the diagram that allow identifying which are the most significant factors, indicating the items that should be prioritized, thus helping organizations to make decisions (MENDES, 2015).
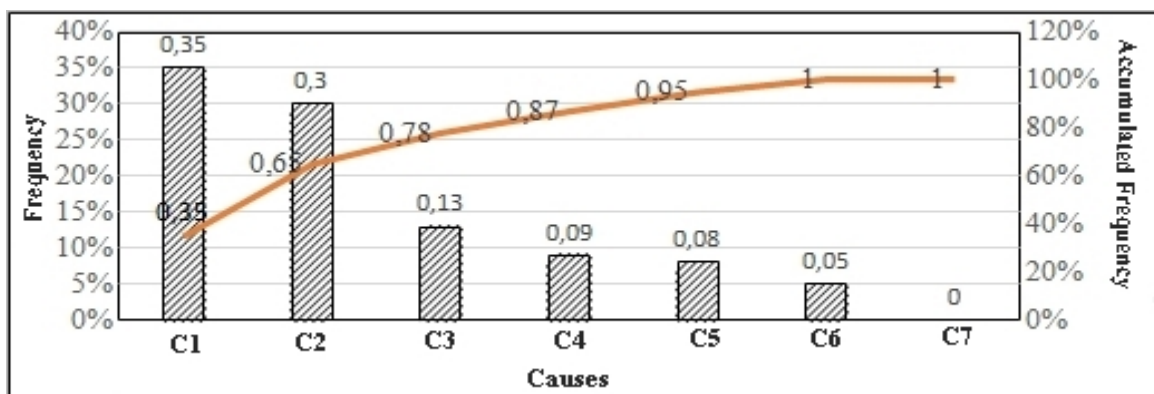
Figure 11: Pareto Diagram

Source: Author (2020)

2.4.3 Ishikawa Diagram

The Ishikawa or Fishbone Diagram (Figure 12) was created by chemical engineer Kaoru Ishikawa in the 1950s, when the Japanese industry flourished, with the help of not only local talents such as Ishikawa, Sakichi Toyoda, Taiichi Ohno, but also renowned American teachers, such as William Edwards Deming.

It is considered an effective tool to diagnose problems in organizations (LUCINDA, 2010), as it allows analyzing the primary and secondary causes of a given problem. Besides, it is possible to assess the effects of problems, act on the causes, and thus create ways to act effectively on them.

This diagram (Figure 12) is well known and it has three main parts:

Part 1 is the Effect, which can be a Problem or a Solution of a process, system or event;

Part 2 is called category or factors divided in four to six parts such as Machine, Man, Measures, Method, Material, and Environment;

Part 3 is composed by the causes.
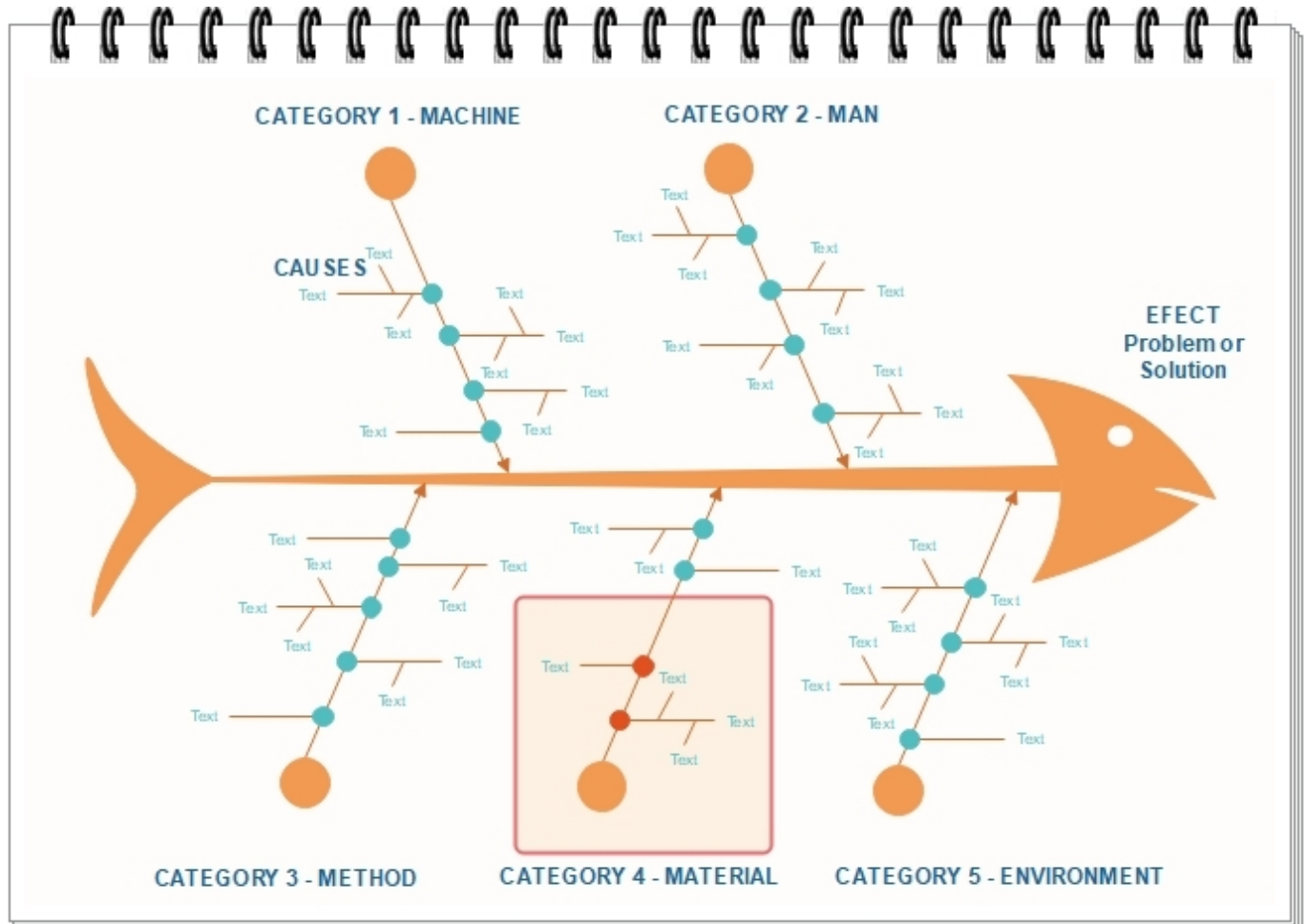
Figure 12: Three main elements (effect, categories, and causes) of the Ishikawa Diagram

Source: EdrawMax <https://www.edrawsoft.com/download-edrawmax.html>

Slack et al (2002) establishes four steps for drawing up the Ishikawa diagram: the first is to define the effect or problem; the second defines the categories of possible problems; the third seeks to identify possible causes for the problem; and finally, the main cause of the effect/problem is defined, as well as possible solutions.

2.4.4 Flowchart

The first flowchart was presented by Frank Gilbert to the American Society of Mechanical Engineers (ASME) in 1921 (SABINO, 2018). It is also called a procedure graph or process graph since it is a graphical representation of the sequence of steps in a process. This tool is used to carry out the documentation of activities, allowing you to easily understand how the process works.

It is a technique used to map processes, which consists of a universal graph that represents the flow of

activities carried out in a process.

This representation is made from geometric figures that symbolize the activities of the process and are linked by arrows that indicate the direction and the sequence to be followed.

Ishikawa (1915-1989), considered the flowchart one of the main quality control tools, along with other complementary tools, such as the histogram, verification sheet, and cause and effect diagram (SABINO, 2018).

The flowchart has the following advantages:

a) facilitates the understanding of the work process;

b) shows the necessary steps to carry out the work;

c) documents and standardizes the process;

d) demonstrates the sequence and interaction between activities/projects;

e) facilitates consultation in case of doubts about the process;

f) shows the responsibilities and relationships between stages and areas involved in the process;

g) it allows to identify bottlenecks, complexities, delays, inefficiencies, and waste;

h) improves the degree of analysis; among other advantages.

For Campos (2014) the flowchart is the initial step towards standardization and understanding the activities carried out in the processes, facilitating the visualization of manufactured products, customers and suppliers, operations, responsibilities, and critical points.

According to Barnes (1977), the flowchart indicates the various operations to be performed during the execution of a process, identifying activities of operation, transport, waiting, inspection, and documentation flow.

In the specialized literature, there are several flowchart models, but for this research, only the vertical flowchart will be addressed (Figure 13), as it is very useful to present the basic information of the sector or department, map processes, connect the symbols, as well as insert the execution time of each activity and the distance covered by the employees responsible for each activity.

For Kanawaty (1992), the vertical flowchart can be classified into three forms:

First) flow chart of the operator with an emphasis on recording the activities performed by the operator;

Second) material flowchart, whose objective is to focus on the material (raw material, parts, others), describing how it should be treated or handled;

Third) equipment flowchart, which records the method of using the equipment.

For Kanawaty (1992), the same form can be used for the three types of flowchart described, what changes is the emphasis given during the study.

Fluxograma Vertical do Processo						
Código do fluxograma: 00025		Página: 01 de 01				

Objeto de Estudo / Material / Produto: Pallets	Atividade		Presente	Proposto	Economia
	Operação	◯	3		
Processo: Recebimento e Armazenagem de Pallets	Transporte	⇨	2		
	Espera	D	1		
Local: Armazém W-42	Inspeção	☐	1		
Método: (X) Presente ( ) Proposto	Armazenagem	▽	1		
Formulado por: Rafael Lima **Data:** 19/03/2016	Distância total (m)		420		
Aprovado por: João Silva **Data:** 23/03/2016	Tempo (min)		105		

	Descrição	Distância (metros)	Tempo (min)	Tipo de Atividade ◯ ⇨ D ☐ ▽	Observações
1	Caminhão estaciona na doca de descarregamento	-	5		
2	Descarregamento dos pallets para a área "Transit"	100	12		Caminhão médio com 10 pallets
3	Conferência do material recebido com NF e *packing list*	-	10		
4	Impressão do relatório de recebimento	20	22		
5	Levar relatório ao motorista e liberar caminhão	10	1		
6	Cadastro dos pallets no sistema e colocação de *tag* RFID	10	22		
7	Empilhadeira armazena pallets nos porta-pallets	250	30		Distância média de 25m por pallet
8	Registro do endereço onde os pallets foram colocados	30	3		

Figure 13: Flow of Receipt and Storage of Pallets.

Source: Aprendendo Gestão <https://bit.ly/2Q2Cxii>

3. Methodology

The research is applied to Industrial Engineering and as for the objectives it is descriptive since it will describe the characteristics of the processes, the parameters, and main problems existing in the deposition of solder paste in the automatic insertion of the organization, without interfering in the studied variables.

For its development, there will be a combination of specific case studies and bibliographic research (articles, dissertations, and theses involving the theme). Also, this study is based on documentary research (records, forms, etc.) with the sectors involved, in addition to the application of quality tools aimed at identifying and solving problems.

The main stages of the research were: 1) map the main activities of the Stencil control to identify each activity, observing the procedures, forms, records, and other documents necessary to execute them; 2) identify the critical factors of quality printing and the effective control of the Stencil to define the critical factors of the

process and its efficiency; 3) to identify the three main problems that exist in the control of the Stencil, as well as their causes through the use of some quality tools; 4) develop guidelines to make Stencil control more efficient, based on the computerization of this process.

4. Discussion

4.1 Mapping of the main activities of the Stencil control

The mapping of the main activities of the automatic insertion Stencil control took place at the beginning of December 2019. For that, a chronoanalysis and a vertical flowchart were used.

In this process there are two types of Stencil control, one process is used when the Stencil is new and the other process is called control when the Stencil is used in the process.

For the case of the control of the new Stencil, Figure 14 shows fourteen activities that require about 1h42min22s to be performed when passing through three sectors.

Fluxograma Vertical					Tempo Processo (horas):		1:42:22

Símbolos								
■	Operação		2	00:05:55	5,78%	Empresa:	Empresa X	
➡	Transferência de Material		5	00:07:40	7,49%	Tipo de Processo:	Padrão	Novo
■	Decisão ou Medida	Total	1	1:20:00	78,15%	Nome Processo:	Recebimento Stencil	
■	Documentação		5	00:08:02	7,85%	Setor:	Inserção Automática	
▼	Armazenagem		1	00:00:45	0,73%	Data:	2/12/2019	

Fase	Símbolos					X Tempo	Acumulado	% Acum.	Descrição
1	☐	➡	☐	☐	▽	00:01:20	00:01:20	1,30%	Coordenador : receber novo Stencil do Almoxarifado.
2	☐	➡	☐	☐	▽	00:01:45	00:03:05	3,01%	Coordenador : enviar e-mail para as áreas técnica e administração informando o recebimento do stencil .
3	☐	➡	☐	☐	▽	00:02:25	00:05:30	5,37%	Coordenador : encaminhar o Stencil para o setor administrativo para realizar a sua identificação e registro.
4	☐	➡	☐	☐	▽	00:05:25	00:10:55	10,66%	Administrativo :imprimir etiqueta de identificação do Stencil
5	☐	➡	☐	☐	▽	00:00:30	00:11:25	11,15%	Administrativo : fixar a etiqueta no Stencil.
6	☐	➡	☐	☐	▽	00:01:25	00:12:50	14,08%	Administrativo : registar na planilha de controle de Stencil
7	☐	➡	☐	☐	▽	00:01:35	00:14:25	14,08%	Administrativo :encaminhar para avaliação da área técnica .
8	☐	➡	☐	☐	▽	01:20:00	01:34:25	92,23%	Área Técnica : realizar a avaliação do stencil.
9	☐	➡	☐	☐	▽	00:01:43	01:36:08	93,91%	Área Técnica : enviar e-mail para a coordenação e administração informando o resultado da avaliação.
10	☐	➡	☐	☐	▽	00:00:45	01:36:53	94,64%	Área Técnica : enviar o Stencil para a área administrativa .
11	☐	➡	☐	☐	▽	00:01:25	01:38:18	96,03%	Administrativo : registar na planilha de controle de Stencil o resultado da avaliação.
12	☐	➡	☐	☐	▽	00:00:45	01:39:03	96,76%	Administrativo : disponibilizar o Stencil aprovado para Produção, a fim de ser armazenado.
13	☐	➡	☐	☐	▽	00:01:35	01:40:38	98,31%	Administrativo : enviar o Stencil reprovado para o descarte.
14	☐	➡	☐	☐	▽	00:01:44	01:42:22	100,00%	Coordenação: solicitar substituição Stencil reprovado

Figure 14: Control Receipt of stencil at Company X

Source: Author

The number of activities performed to obtain control of the Stencil was:

a) two activities (14%) related to the operation, which takes 5min55s to be executed, representing about

6% of the total activity time;

    b) five activities (36%) related to material transfer, which takes about 7min40s to be carried out, representing about 7.5% of the total time required for the activities;

    c) an activity (7%) related to the decision or measurement, but which consumed 1h20min, representing 78.15% of the total activity time;

    d) five activities (36%) related to documentation, which consumed 8min2s to be performed, representing about 8% of the total time of activities;

    d) an activity (7%) related to storage, which takes only 45s (0.35% of the total time).

For the case of the control of the Stencil used, Figure 15 (Appendix A) shows 29 activities with 42 min 44s to be performed by the operator, as well as by employees in the technical and administrative area. The number of activities performed to obtain control of the Stencil used was:

    a) seven (24%) activities related to the operation, which take 23min27s to be carried out, consuming a little more than half (55%) of the total time of the activities;

    b) four (14%) related to material transfer, which takes about 4min13s to be executed, representing 9.87% of the total time required for the activities;

    c) seven (24%) related to the decision or measurement, but which consume 4min45s, representing 11.12% of the total activity time;

    d) ten (34%) activities related to documentation, which consume 9min44s to be performed, representing almost 23% of the total activity time;

    e) one (3.4%) related to storage, which takes only 35 seconds to execute.

4.2 Mapping of Stencil control instructions and documentation

Eight work instructions and nine forms necessary to carry out the Stencil control were identified. Table 4 shows the activities with their respective work instructions and forms, identifying the need to make improvements in 75% of the documents, as well as the preparation of a new instruction.

Table 4 – Table of activities indicating the Instructions and the number of forms for the Stencil control

Activity	Instruction	Sector	Number of Forms	Other types	Needs Change
Receive Stencil	IT XX.0001	Coordenation	0	E-mail	Yes
Identify and register	IT XX.0002	Administrative	1	-	Yes
Evaluate New Stencil	IT XX.0003	Technical	0	E-mail	Yes
Make Available for Production	IT XX.0004	Administrative	1	-	Yes
Evaluate Stencil Process	IT XX.0005	Productive	1	-	No
Clean the Stencil	IT XX.0006	Productive	2	-	Yes
Control the life of the Stencil	IT XX.0007	Productive	2	-	Yes
Measure voltage	IT XX.0008	Technical	2	-	No
Revalidate service life	None	Technical	0	E-mail	-

Source: Author

4.3 Critical factors of quality printing and effective Stencil control

4.3.1 Factors that influence good printing

The authors, Fleck and Chouta (2003 p. 25), argue that the design of the Stencil is one of the most important factors that determine a functional production in an electronic assembly plant.

This development depends on several factors such as the layout of the PCB, the materials, the components used, etc.

Fleck and Chouta (2003 p. 25) created a diagram (Figure 16) that identified four categories and several causes that influence quality printing.
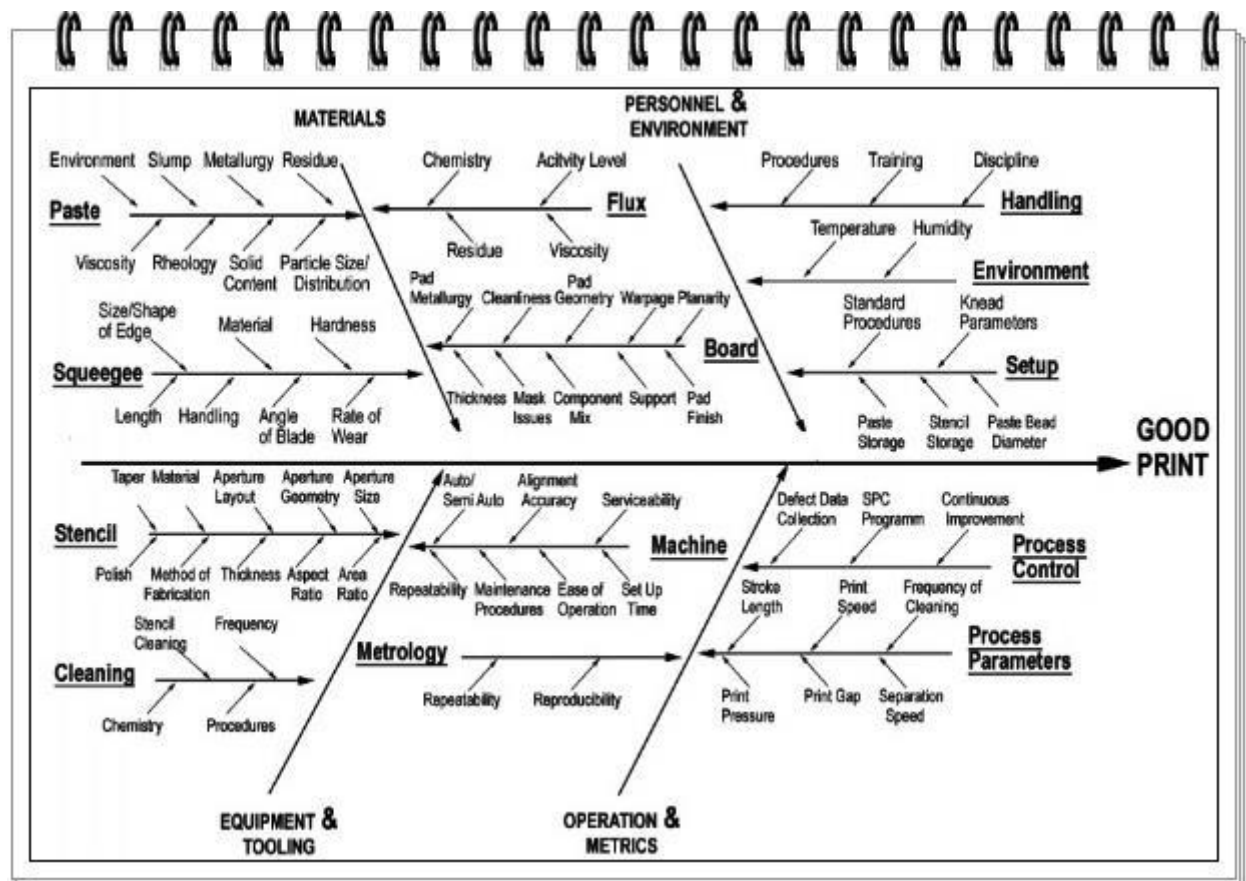
Figure 16: Categories that influence quality printing

Source: Fleck and Chouta (2003 p. 25)

Altogether there are about 71 causes that contribute to an effective Printing, most of which are in the Materials category with 29 causes (40.8%), followed by Equipment and Tools with 21 causes (29.6%), ten of which are linked only to Stencil. Then come the category Operation and Metrics with 11 causes (15.49%) and the category Personal and Environment with 10 causes (14%).

4.3.2 Factors that influence Good Control of Stencil at Company X

A study was carried out in early December 2019 with the team that controls Stencil at Company X, to identify the main factors that contribute to this service being considered good.

As a result, Figure 17 shows about twenty-four causes that need to be monitored by the process team.

The effect hoped is The Good Control of Stencil and the analysis shows that:

a) most of the causes are in the Method category (Figure 17) with ten (41.66%) that involve everything from the handling, correct identification of the Stencil, the disposal process, the existence of documented procedures, to methods to evaluate the process and the new Stencil, etc.
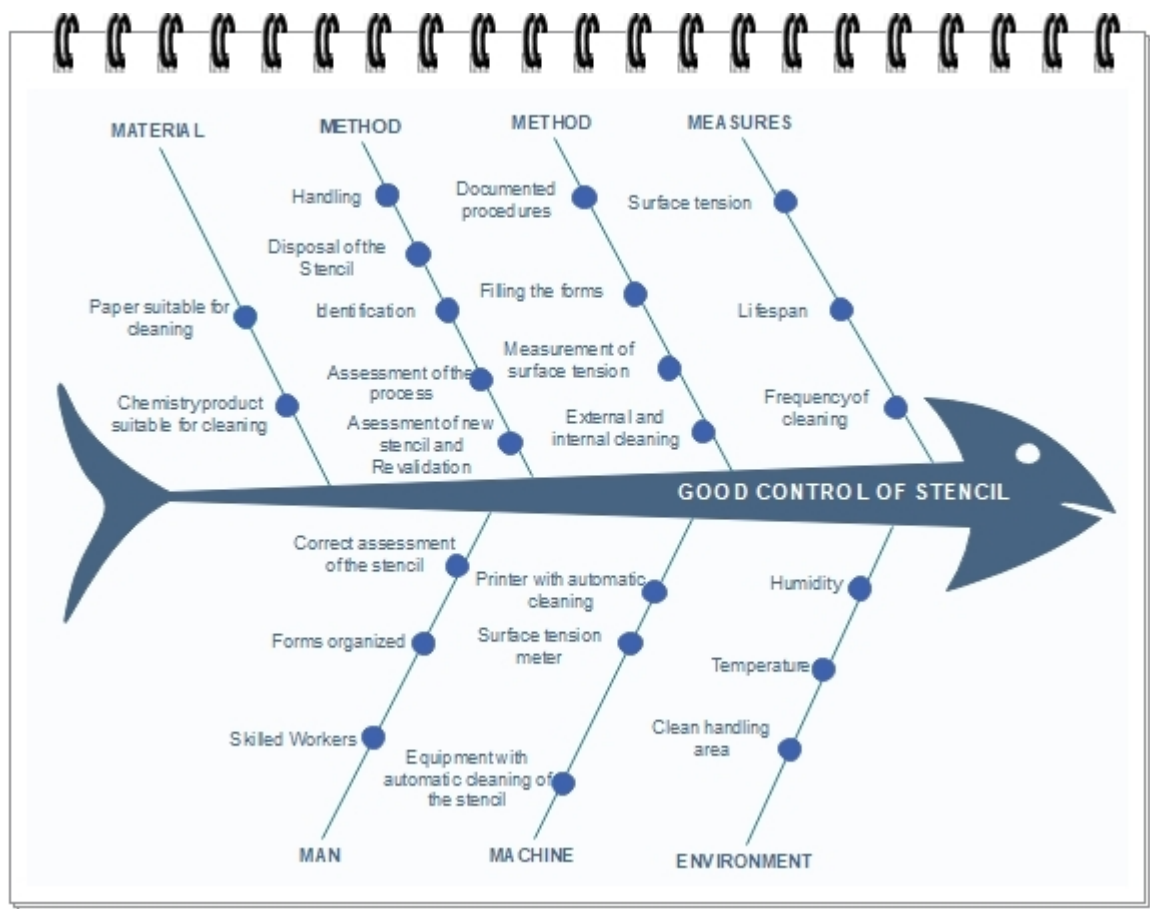
Figure 17: Categories and causes that contribute to a good control of the Stencil at Company X

Source: Author

The three causes (12.50%) in the Measures category are surface tension, lifespan, and cleaning frequency, whereas, in the Environment category, humidity, temperature, and cleaning of the handling area are another 3 causes considered relevant (12.5%).

In terms of the Machine category, another 3 causes were considered crucial were the automation of cleaning the Printer and the Stencil, as well as the superficial tension meter.

For the Man category, good printing requires qualified, organized personnel with the capacity to make the correct evaluation of the Stencil.

Finally, the Category with the fewest causes (2; 8.33%) is Material, focused on paper and chemical products suitable for cleaning the Stencil.

To ensure repeatability in the process, it is essential that all methods implemented are properly documented and employees are properly qualified.

Any changes made to the processes must be reviewed and the impacts of these changes on the quality of the product must be evaluated by specific procedures and trained employees.

In this way, a record of the history of problems and, consequently, the actions are taken to solve them are kept, which allows employees to prevent routine problems.

4.3.3 Main problems with Stencil control and solutions

A study carried out between May and September 2019, involving 37 Stencils in each of the nine activities performed (Table 4), revealed (Figure 18) that most of the failures occurred in the activities of evaluating new stencil (37), measuring surface tension (37), in lifespan (37), and revalidation (37).
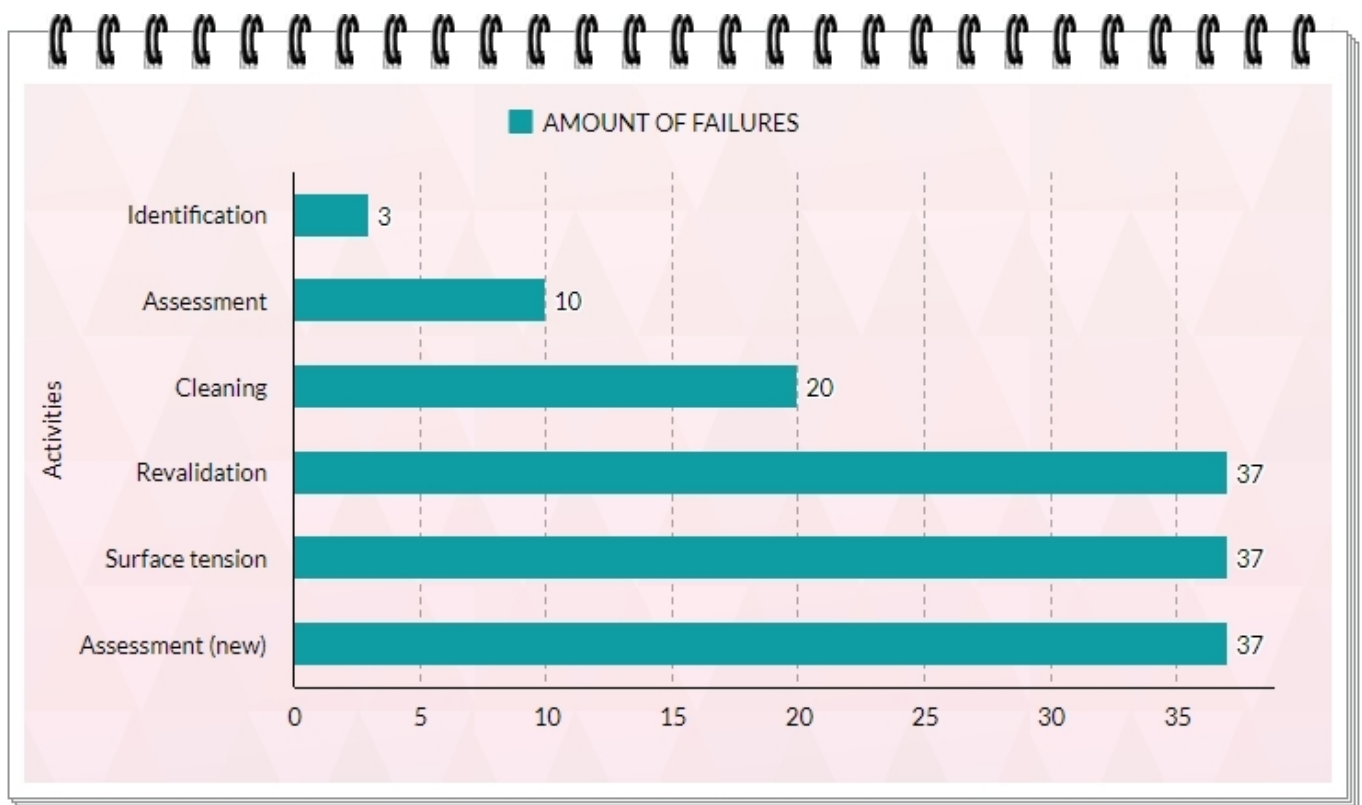
Figure 18: Number of failures in Stencil control activities

Source: Author

The evaluation activities of the new stencil, measurement of surface tension, and revalidation are performed by the Technical Area of Automatic Insertion. While the identification activities are carried out by the administrative area of production and the others are carried out by the machine operators.

Regarding the new Stencil Assessment activity, no records of the verifications carried out were evidenced, but after informal conversations carried out by those responsible for these assessments, it was found that all those responsible were trained to carry out this activity, and the inspections were, in fact, carried out, but there was a failure in its documentation.

It was also found that in the Stencil Assessment instruction there is no form or checklist to be completed during the performance of this activity. Also, it was evident that no documented process identifies whether the Stencil was evaluated before being released for production, this can cause production stops since the stencil may contain flaws in the manufacturing process.

In the instruction of the surface tension measurement activity, there is a form defining, a methodology and parameters to be used in the measurement. However, in the 37 Stencils evaluated, the measurements were not evidenced. In informal conversations with those responsible, they informed that they were trained, but did not measure surface tension.

In the activity of the Stencil's lifespan, the records of the 37 Stencils were evaluated and the following flaws were detected:

a) no Stencil identification information;

b) failure to complete the number of cycles performed on certain days;

c) wrong sums;

d) the stencils were not sent for revalidation by the technical area;

e) lack of records or records not found.

In conversations with employees, they reported that they were trained for the Stencil's useful life activity, but have difficulty doing it, as they are focused on achieving productivity goals. Besides, 19 lines (79.17%) are operated by only one operator, which makes Stencil control activities even more difficult.

The revalidation activity is directly related to lifespan activity. After the Stencil completes its useful life, the machine operator must send it to the Technical Area for revalidation. And as there was a failure in the activity of controlling the life of the Stencil, consequently, the revalidation activity was not performed. The results recorded in Figure 19 show that the main failures that occurred in the control activities of the Stencil were human:

a) unfilled form (74);

b) activity not performed (37);

c) failure to register the activity (30);

d) empty form fields (20).

In informal conversations with employees, it was revealed that they prioritize achieving production goals, leaving other activities in the background.
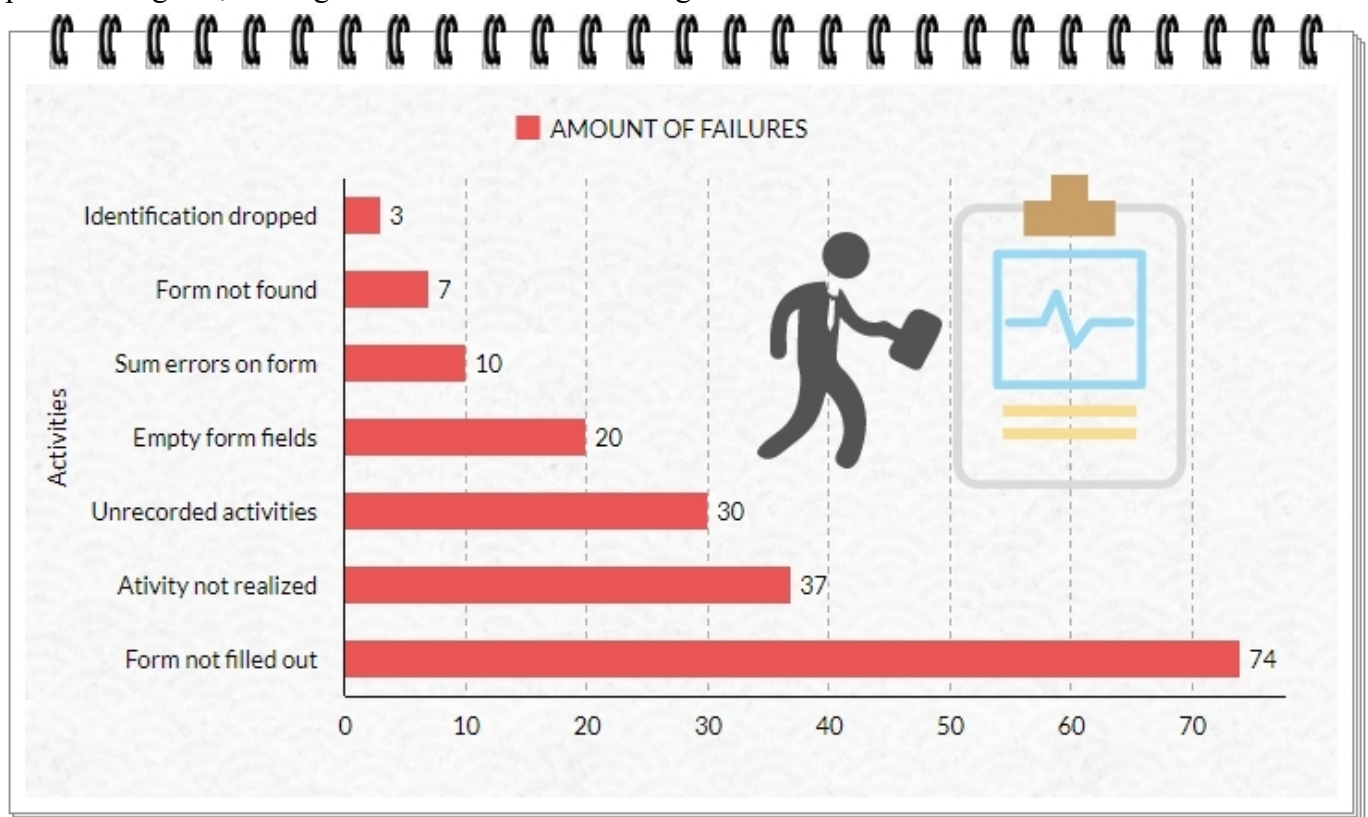
Figure 19: Number of failures in Stencil control activities

Source: Author

4.3.4 Guidelines for the computerized system to make Stencil control effective.

The guidelines were organized into two groups, the first contains general guidelines for the system and the second contains guidelines for effective stencil control.

The guidelines were developed in the first two months of 2020, based on the flaws detected in this research, in meetings with AI Leaders and Supervisors, as well as in documentary research in the process audit reports issued by customers and by quality control, it is worth mentioning that during system implementation, new needs may arise.

The system to be developed should provide the control of all activities inherent to the control of the Stencil and eliminate the activities of filling out forms by employees, thus freeing them for related activities.

To minimize the costs of implementing the system, hardware already existing at Company X should be used, as well as using the existing production monitoring system to collect data and use the funds earmarked for research and development (R&D), which are governed by information technology law in the Amazon (Law No. 8387 of 12/30/1991).

4.3.4.1 General guidelines for the system

a) define means to identify each Stencil using a bar code or QR code;
b) define means to identify production lines and sectors in the AI production area;
c) create a user profile to perform Stencil control activities;
d) create an automatic notice to those responsible when an action is necessary;
e) not allowing the use of the stencil if one of the activities has not been completed;
f) develop a traceability mechanism to locate the Stencil;
g) create control of the quantity of Stencil requested per project;
h) control Stencil of third parties (customers);
i) have a database with a history of the improvements implemented in each Stencil;
j) be able to register the equipment used to control the Stencil;
k) not allowing the use of equipment that is out of calibration;
l) register the parameters used in the process;
m) be able to record problems and actions taken in the process;
n) be able to register qualified employees;
o) be able to register materials qualified for use in the process;
p) stop production when an activity is not performed;
q) eliminate printed instructions, using only a digital document.

4.3.4.2 Guidelines for Stencil Control

In the control of the stencil (Figure 17) there are about twenty-four causes that must be observed for the service to be performed correctly, so it is recommended:

a) digitize the documents of this process, as described in Table 4;
b) digitize stages of each of the activities involved in this process;
c) create a database that allows managing the parameters involved in this process, as well as preparing reports with indicators over time, involving the monitoring of the causes considered crucial pointed out in Figure 19;

d) develop an alert system to prevent errors or inform those involved in any abnormality in the process;

e) create alerts on the disposal of the stencil, informing the reason for the disposal, maintaining the history, which can be used to generate action plans;

f) inform if the equipment used needs calibration before being used in the process;

g) develop a robust label to be attached to the Stencil, to prevent it from falling.

5. Conclusions and recommendations

The general objective of the article is to provide subsidies for the development of a computerized system for the control of the Stencil in the Printing process sub-process of the SMD line of Company X From the analysis of articles, documents, and data, the following conclusions and recommendations were reached:

a) the best way found at Company X to provide developers with useful information that contributes to the effectiveness of the computerization of the stencil control involves mapping activities, studying the documents involved in the processes, identifying the main problems, conducting meetings with those responsible to analyze the causes, propose solutions, as well as the guidelines;

b) nine activities were identified to carry out effective Stencil control at Company X: 1) receive Stencil; 2) identify and register; 3) evaluate new Stencil; 4) make available for production; 5) evaluate Stencil in the process; 6) clean Stencil; 7) control the life of the Stencil; 8) measure surface tension; and 9) revalidate the Stencil's useful life;

c) at Company X, the control of the Stencil is done using eight work instructions, nine forms, and there is a need to create a procedure for the activity of revalidating the life of the stencil. It is recommended that all instructions and forms are computerized, and it is also necessary to include new instructions and forms to c1) control the Stencil of third parties; c2) the control of the amount of Stencil used in a given product; c3) control of equipment used in the control, among others;

d) the research found 4 categories and 71 potential causes that guarantee good results in the Printing subprocess, with the majority being in the Materials category with 29 causes, followed by Equipment and Tools with 21 causes, ten of which are connected only to the Stencil. Next comes the Operation and Metrics category with 11 causes, and the Personal and Environment category with 10 causes. At Company X, new research can be carried out to deepen the study of causes that are not linked to the Stencil, to improve printing over time;

e) at Company X, 24 causes affected the performance of the Stencil control, and it was observed that the main failures that occurred were human: form not filled out, an activity not performed, an activity not recorded, empty fields. Informal meetings with employees revealed that they prioritize achieving production goals leaving other activities in the background, which is why the guidelines for the computerization of this process become relevant;

f) for computerization developers, 24 guidelines were proposed, the main ones being: defining means to identify each Stencil using bar code or QR code; do not allow the use of the Stencil if one of the activities has not been completed in the process; stop production when an activity is not performed; digitize the documents used in this process; create an automatic notice to those responsible when action is needed. New research can be carried out to measure the impact of adopting the suggested guidelines on costs, productivity, and quality improvement over time, such as, for example, a year with the new system compared to the previous year's indicators without the system.

Another recommendation is to identify new bottlenecks in the processes and find ways to insert techniques or technologies from Industry 4.0 to improve the performance of Company X, as the Industrial 4.0 revolution is a solution adapted to face the scarcity of resources, inefficiency of processes, and reduction of waste.

7. Acknowledgments

8. Appendix A

Fluxograma Vertical			Tempo Processo (horas):	0:42:44

Símbolos		Total				
▬ Operação	7	00:23:27	54,88%	Empresa:	Empresa X	
➡ Tranferência Material	4	00:04:13	9,87%	Tipo de Processo:	Padrão	Novo
◆ Decisão ou Medida	7	0:04:45	11,12%	Nome Processo:	Controle Stencil no Processo	
▬ Documentação	10	00:09:44	22,78%	Setor:	Inserção Automática	
▼ Armazenagem	1	00:00:35	1,37%	Data:	02/12/2019	

Fase	Símbolos	X Tempo	Acum.	% Acum.	Descrição
1		00:02:20	00:02:20	5,46%	Operador de máquina: localizar stencil para realizar set-up da linha conforme plano de produção.
2		00:00:40	00:03:00	7,02%	Operador de máquina: registrar a transferência de local do Stencil no Formulário.
3		00:01:25	00:04:25	10,34%	Operador de máquina: avaliar o Stencil (Limpo/ Danificado...).
4		00:00:30	00:04:55	11,51%	Operador de máquina: registrar a avaliação no Relatório de Produção.
5		00:01:00	00:05:55	13,85%	Operador de máquina: caso haja problema informar a Coordenação.
6		00:01:10	00:07:05	16,97%	Operador de máquina: localizar o formulário de controle da vida útil do stencil .
7		00:00:10	00:07:15	16,97%	Operador de máquina: verificar se o formulário corresponde ao stencil.
8		00:00:05	00:07:20	17,16%	Operador de máquina: avaliar se vida útil esta dentro da validade (número de ciclos na printagem).
9		00:00:30	00:07:50	18,33%	Operador de máquina: registrar no Relatório de Produção o resultado da avaliação.
10		00:00:20	00:08:10	19,11%	Operador de Maquina : Dar inicio a produção
11		00:15:00	00:23:10	54,21%	Operador de Maquina : Realizar limpeza do stencil conforme periodicidade definida na folha de set-up.
12		00:01:25	00:24:35	57,53%	Operador de Maquina : Avaliar as condições do stencil após limpeza.
13		00:00:30	00:25:05	58,70%	Operador de Maquina : Registrar no Relatório de Produção o resultado da avaliação.
14		00:00:02	00:25:07	58,78%	Operador de Maquina : Realizar controle vida útil do stencil.
15		00:00:30	00:25:37	59,95%	Operador de Maquina :Registrar no Formulário quantidade de ciclos realizados com stencil no final do turno de trabalho.
16		00:00:35	00:26:12	61,31%	Operador de Maquina : Avaliar se stencil necessita ser enviado para teste de tensão superficial, conforme números de ciclos
17		00:01:00	00:27:12	63,65%	Operador de Maquina : Enviar para a área técnica o stencil para teste tensão superficial.
18		00:03:25	00:30:37	71,65%	Área Técnica : Realizar teste tensão superficial.
19		00:00:30	00:31:07	72,82%	Área Técnica : Registar medição no formulário.
20		00:01:44	00:32:51	76,87%	Area Técnica : Caso medições estejam fora do especificado enviar e-mail informando a Coordenação e Administrativo.
21		00:00:35	00:33:26	78,24%	Área Técnica : Enviar para Admnistrativo
22		00:01:10	00:34:36	80,97%	Administrativo : Registar na Planilha de controle de Stencil.
23		00:02:35	00:37:11	87,01%	Administrativo : Enviar o Stencil reprovado para Descarte.
24		00:03:10	00:40:21	94,42%	Coordenação : Solicitar substituição Stencil reprovado
25		00:00:05	00:40:26	94,62%	Operador de Maquina : Fim do plano de produção.
26		00:00:03	00:40:29	94,73%	Operador de Maquina : Tranferir stencil da Produção para Armario de Stencil.
27		00:00:35	00:41:04	96,10%	Operador de máquina: Armazenar stencil no armário de stencil.
28		00:00:30	00:41:34	97,27%	Operador de máquina: registrar a transferência de local do Stencil no Formulário (Produção para Armário).
29		00:01:10	00:42:44	100,00%	Operador de Maquina : Verificar plano de produção ,

Figure 15: Stencil control in the process

Source: Author

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