Importance of the Application of Lean Manufacturing and Sustainable Manufacturing and Its Impact on Productivity and Quality in the Electronics Industry of Mexicali

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Abstract: An evaluation of use of lean and sustainable manufacturing tools was made, correlating them with the productivity and quality indices in an industry of the electronic sector located in the city of Mexicali. In this evaluated company, it was observed that some improper manufacturing methods was used and for this reason, generated a large amount of waste from electronic devices and electronic boards. This caused the productivity and quality indices to decrease, originating the need for extra time and with it unnecessary costs that devalued the prices of manufactured products, due to the competitiveness in the electronic industry sector evaluated. With the application of tools of lean manufacturing and sustainable manufacturing, the productivity and quality levels were increased and both overtime and unnecessary costs were reduced, achieving competitive prices in the evaluated industry. The installation method of electronic components with polarity in electronic boards was evaluated, due to the fact that a great diversity of products emerged from the automatic insertion area with defects, indicating reversed polarity, which should be solved, otherwise, short circuits could be generated or lack of electrical conductivity, in the manufactured products in their final process. This caused the manufactured products to not work properly, causing the presence of defective products and with it low levels of productivity and quality and economic losses. and It was detected that this occurred due to the lack of training of the operative personnel and the neglect of the operative workers of the automatic insertion area. In order to control this situation, as a methodological part, schematic models were developed to support the operational personnel in their activities in the automatic insertion area. This proposal with the schematic models developed for use in the electronics industry, where the research was made. The study was developed from 2018 to 2019.

Keywords: Lean manufacturing, sustainable manufacturing, electronics industry, productivity and quality indices.

I. INTRODUCTION

One of the main challenges of each industry at a global level is to reach the maximum levels of competitiveness with the optimization of industrial processes by applying Lean Manufacturing (LM) tools, and relating it to the application of efficient Sustainable Manufacturing (SM) strategies[1]. This relationship has greatly supported the improvement of productivity rates, because lean manufacturing methods have been applied with the main objective of increasing production and quality rates with the least amount of personnel. This is considered, in conjunction with the use of the machinery and equipment, with the objective to eliminate the large generation of errors that was caused defective products and thus solid waste[2]. In addition to the lean manufacturing analysis, sustainable manufacturing strategies have been evaluated to use natural resources optimally (especially energy and water) in any region of the world in manufacturing processes, and generate awareness of caring for the environment. This has been done to obtain the least amount of air pollutant emissions into the atmosphere, as well as to avoid creating situations of generation of large amounts of industrial waste, whether solid or liquid. These, when discharged to the ground, was caused contamination in soil and water around the electronics industry evaluated. The aforementioned is illustrated in figure 1, observing the link through three factors of lean manufacturing with the sustainable manufacturing, with the (1) waste elimination, (2) use of the continuous improvement tools and (3) analyze of productivity and quality indices. The three factors have a close relationship between the LM and SM, using development of simple and complex strategies, with which waste was reduced of the industry analyzed, achieving until it is eliminated and increasing productivity and quality indices.

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That is why the link in figure 1 was visualized, with the impulse of the generation of innovative ideas applying them quickly and efficiently in the manufacturing areas of the industry evaluated.

This was, to apply simple tools as inspection or control guides, or complex as the use of low-cost automated systems, being both of industrial type; as well as environmental control devices to achieve optimal manufacturing processes[3].The relationship between LM and SM showed in figure 1, as a descriptive model, with which was detected very fast and easy the problematic situation in the manufacturing areas.
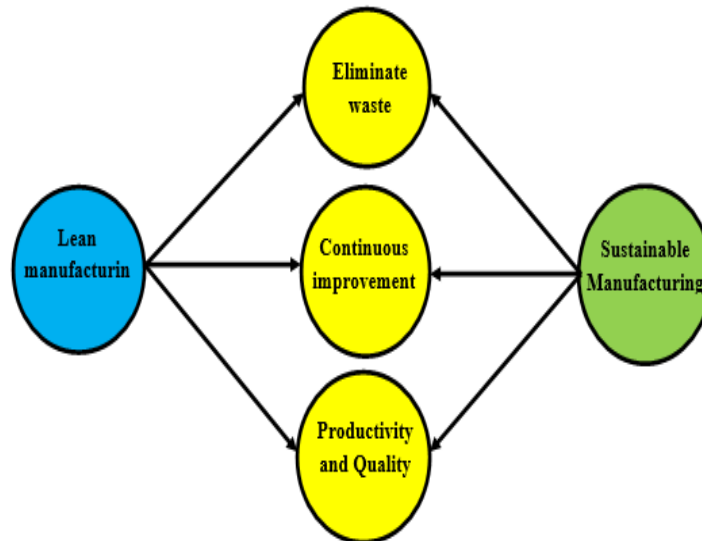

Fig. 1.Relationship of LM with SM

The lean and sustainable manufacturing in the electronics industry

One of the industries that presents a problematic situation of generation of waste, and is created in large quantities as solid waste is the electronic branch, which is solid, with defective electronic components or boards[4,5]. Sometimes they are received in that state or sometimes due to planning errors, programming or carelessness of the operating personnel, they are damaged, causing accumulations of defective products or materials in areas of manufacturing areas as defective by-products, in unnecessary containers or landfills. These types of analyzes have been developed to constantly increase production and quality indices based on efficient productivity, evaluating the appropriate use of natural resources (water and energy) in each region of the world that help ensure them for future generations[6]. In addition, efficient manufacturing techniques with LM are contemplated, as well as the evaluation of SM strategies with an optimal operation of industrial processes with the least amount of water and energy consumption, and the development of renewable energy sources. Tactics are also established for the manufacture of products that are biodegradable easily and quickly, avoiding the large accumulation that exists globally of non-functioning or obsolete products that generate huge amounts of solid waste that reduce air pollution rates, water and soil[7]. This is why various experts in the area of industrial and environmental engineering have evaluated the possibility of integrating the LM and SM methods. Based on this, both the maximum operational performance of the personnel and industrial equipment and machinery are analyzed. In addition, efficient manufacturing methods that do not generate waste

are meticulously analyzed, as well as an evaluation of natural resources of each region of the world, so that they are optimally used in the transformation of raw materials into manufactured products. This is done in various sectors of industrial plants established in the city of Mexicali, where around 150 companies are located, being 70% of the electronic branch or they use electronic components or devices[8].Since the lean manufacturing was implemented in the electronics industry, continuous improvement techniques have being developed with which the waste chain, inventory and spaces where unfinished products are stored have been considerably reduced, being a more fluid process. In addition, the processes have been strengthened, having efficient material delivery activities and improving plant distribution and achieving greater flexibility in processes with a diversity of products. This is of great importance in the electronics industry due to the high levels of competitiveness that exist and the need to manufacture various types of electronic products quickly and that is expressed in figure 2. And also, once the sustainable manufacturing was detected as a necessity in the electronics industry, was evaluated the main factors that helped the development of activities to conserve the environmental environment around the industries, being three mainly[9]: (1) minimization of the negative impact on the environment, (2) adequate transformation of energy and (3) conservation of natural resources, as shown in figure 3. This improved the productivity and quality indices.
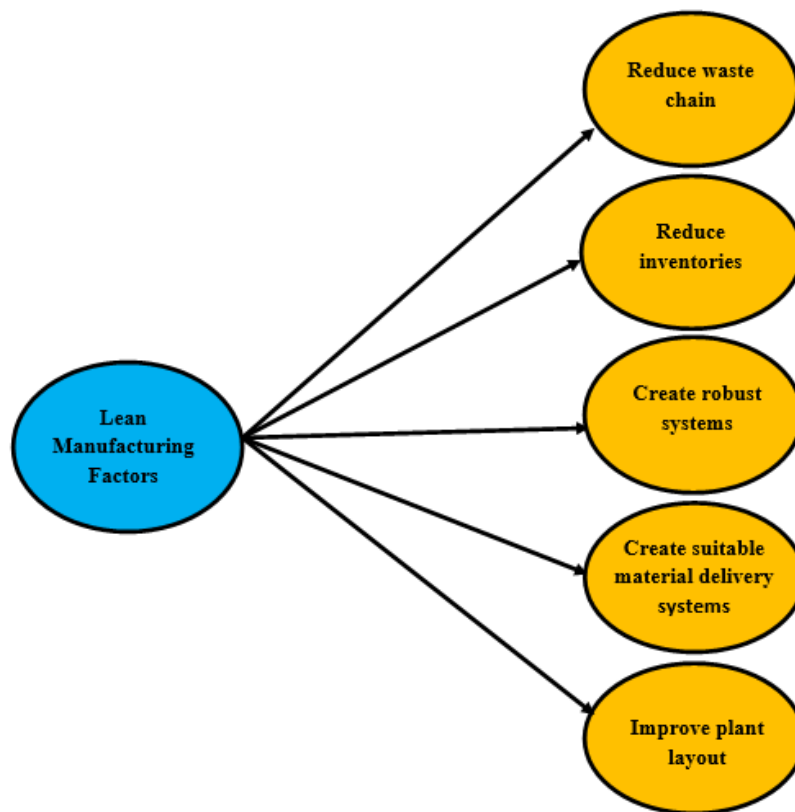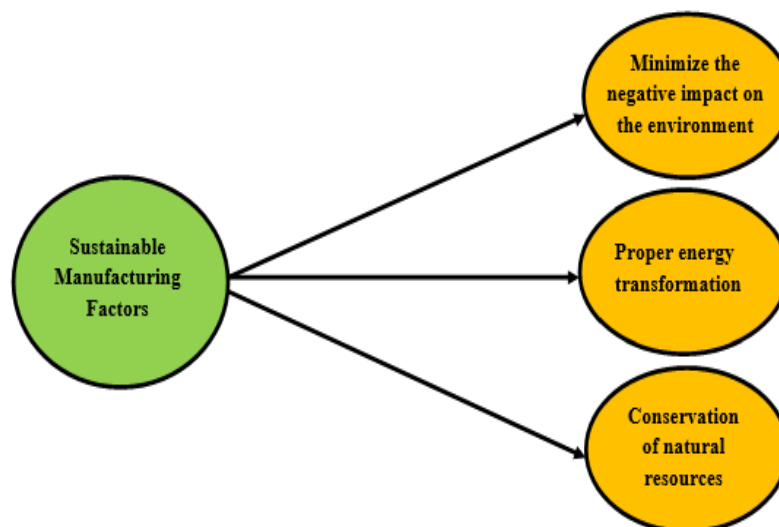
Fig. 2.Lean manufacturing objectives

Fig. 3.Sustainable Manufacturing Objectives

Lean and sustainable manufacturing evaluations

The operability of the industrial equipment and machinery and human resources of the electronics industry evaluated was impacted on the productivity and quality indices, as well as the operating characteristics of manufactured products[10]. This was evaluated on based of certain standard patterns that were determined according to their functionality, and represented by various indicators, an example being the percentage factor. The most common parameters analyzed in industrial processes are the levels of productivity, quality, production, use of natural resources and the impact of emissions generated in the manufacturing areas in each industry that may have a harmful effect on the health of their workers or of the annexed population where the industrial plants are located. To achieve the process of measuring numerical standards, evaluation models were developed that are designed and applied depending on the operation of industrial equipment and machines and human resources at each step of manufacturing[11]. The evaluation models contain indicators that need to be analyzed according to certain measurement stages with the following questioning the investigation was made:

1. How was made a measurement in a manufacturing processes. Some instruments were used to measure times and movements of workers in each step of industrial processes.

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2. How use strategic methods. Measurement methods were determined based on the instruments and devices used, to know the functionality of industrial processes.

3. Reasons of made a measurement. They were carried out with the objective of knowing the operational performance of industrial equipment and machines and personnel working in the manufacturing areas.

4. When and how much was necessary to measure. In certain industrial processes, the measurement was made from the beginning to the end of each turn. This was in different periods: hourly, daily, weekly, monthly, seasonally and yearly, in any manufacturing activities, according to the operational yielding of industrial equipment and machinery and human resources, in according to the necessity in the industrial processes.

Measurements can be simple using simple instruments of measurement of the functions of industrial equipment and machinery and the operation of workers in the manufacturing areas. And on other occasions was used specialized instruments were required to obtain the required values. Lean manufacturing measurement parameters were productivity, production and quality indicators, and sustainable manufacturing were the emissions of gases or particles into the air within the evaluated industry, and the possible effect on the environment of the functionality of the manufactured products. The measurements were elaborated with performance tests, having an objective to be measured the values required and the validation of them measured parameters[9].

Triple relation in industrial electronics

Productivity is an important factor in the industrial plants of Mexicali focused in the electronics sector, and every day the industries apply sophisticated strategies to improve competitiveness, and for that reason, they are constantly analyzing manufacturing methods and techniques to obtain the maximum benefit from material and human resources[12,13] Is very important the integration between lean manufacturing, sustainable manufacturing and productivity (considering it as the triple relationship, based on the fact that they must work together[14, 15]. This to have a firm structure in the elaboration of manufacturing activities, to obtain a well-integrated scheme of the relationship of LM and SM. There are some studies, which mentions that when companies present limitations in the adoption of the close link between ME and MS, it generates results of interest, which increase the levels of competitiveness of the industries using tools and strategies of lean manufacturing and sustainable manufacturing[16].

II. METHODOLOGY

Each step of the industrial process of the automatic insertion area was evaluated, four of which are explained below:

a) Step 1. In the manufacturing area where was made the investigation of the electronics evaluated, there are four machines called sequencers that developed a sequence of electronic components with the required positioning for the following stages, obtaining the sequence of around 100 electronic components adhered with adhesive tape.

b) Step 2. In the manufacturing area analyzed, there are four axial-type machines, where electronic components are installed horizontally, such as coils, capacitors, rectifier diodes, zener diodes and 1/4 watt power resistors, as well as wires steel used as electrical connections.

c) Step 3. In the industrial processes, there are four radial-type machines, which vertically install electronic components such as electrolytic capacitors, coils, regulators and 1/2 watt power transistors, which elaborate different functions with higher voltage and electric current capacity the electronic components installed in the previous stage.

d) Step 4. The manufacturing area evaluated, there are four machines for analyzing the positioning of the electronic components installed in stages 3 and 4 and it is here where they found out about defective products when at times there were almost thousands of by-products manufactured from these in periods four hours.

Results

For this investigation, production and quality levels were evaluated from 2018 to 2019, observing in statistical information of the electronic industry analyzed, that the productivity indicators were not met, due to the generation of human errors in the facilities of the materials, to be processed in the automatic insertion area of this industrial company where was made the investigation. In addition, programming errors were presented and electronic boards were obtained as by-products with electronic components in wrong locations, damaging the electronic elements in the form of raw material or with polarity among the most common. The reverse polarity defect was the one with the highest percentage presented; causing electrical failures in the electronic boards and with it rework activities, so this was the main factor of the investigation made. In the production processes of the electronics industry, there is a diversity of activities, where various types of equipment and industrial machinery are used coupled with manual activity operations, and with simple and complex specialized methods. As industrial equipment and machinery operate at very fast speeds sometimes or sometimes moderately, and if the proper methods or trained personnel are not used, many defective products can be generated, being a problematic situation for every industry in the electronics sector. One of the cases of problematic situations that occurred more frequently in the automatic insertion area, with industrial equipment and machinery operating at high speed, was the improper placement of electronic components with polarity in the first step. In this case, the sequence was elaborated of union of the electronic components that will be inserted in electronic boards in a second step in an automatic inserting machine. Another case occurred, when the electronic boards are placed in an inverted way in the automatic insertion machines or the operation programs of this type of industrial machines. This originated electronic boards with electronic components with the reversed polarity, being defective products and if not quickly detected, up to thousands of electronic boards can be generated in an eight-hour shift. With this, was caused a rework activities being considered as unnecessary costs as the accumulation of garbage, where were kept the defective products in areas inside of the electronic industry evaluated, which caused soil contamination and damage to the ecosystems around of this electronic industry.

Based on this, economic losses arise from unnecessary rework costs and possible fines from customers for late delivery of manufactured products. When this happened, sometimes in the rework a part of the materials (electronic components and electronic boards) was recovered. This required that raw material from another type of product be used with some similar electronic components and thus causing an incomplete product process, being a fundamental part of the economic losses. This lowered productivity and quality indices, reducing economic profit margins. This is showed in a descriptive diagram in Figure 4.
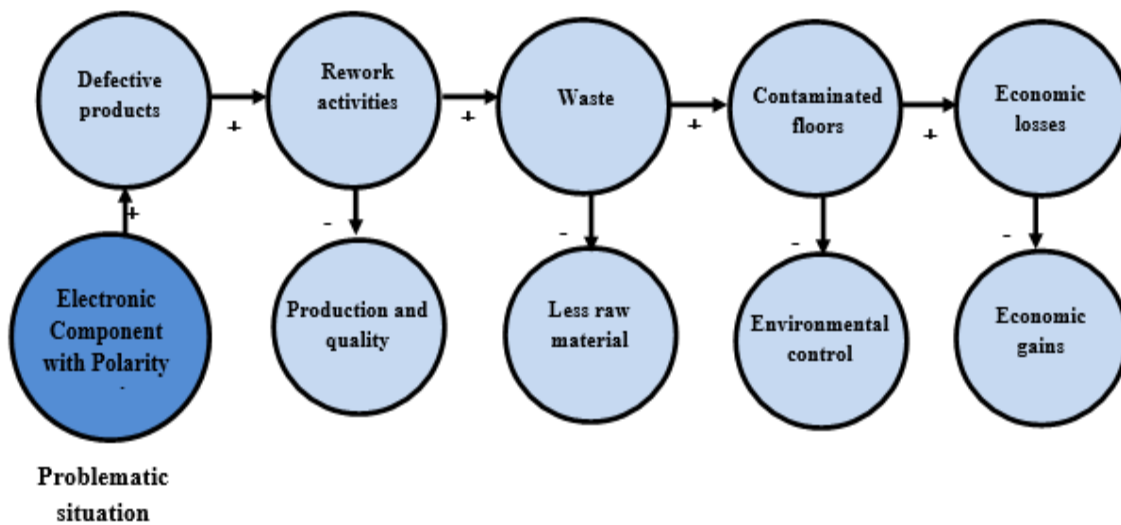

Fig. 4.Analysis of waste generation of electronic components in electronics industry

Solution analysis with lean manufacturing

Once detected one of the main problematic situations that occurred in the auto insertion area of the electronic industry evaluated, an analysis was developed for a solution proposal, where it was evaluated in stages, elaborating a guide on how to carry out the activities to avoid the generation of defective products. The guide for the placement of electronic components is based on figure 5, with a series of stages designed by industrial process engineering specialists in the industry evaluated, and together with manufacturing and environmental experts of the education institution participates in the investigation.
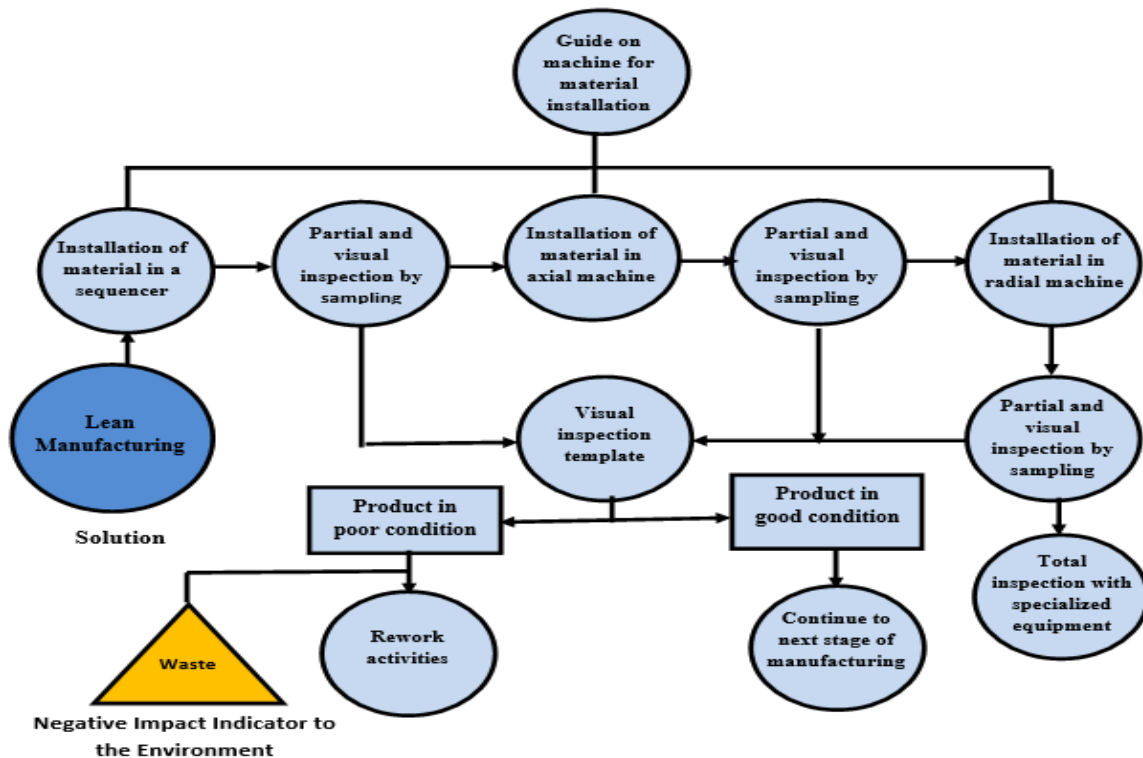

Fig. 5.Solution analyses with slender manufacturing methodology

The process consisted as a first stage an adequate awareness of the operating personnel of the sequencer area for the correct installation of electronic components with polarity, supported by a support guide for the rapid detection of the polarity of the electronic components. After this, a visual inspection of the operating personnel, and a supervisor of the sequencer area was developed. Then the same process of the sequencer was developed in the axial insertion machine with the same operating personnel monitoring procedure and the area of this type of machines, being the same process for the radial insertion machine. Finally, you have the analysis machine of the electronic components inserted in the automatic insertion area, for subsequently shipped to a manual insertion area. In the event that some defective products of this type of problematic situation of electronic components with inverted polarity are generated, these defective products are going to an area of the automatic insertion area for the reservoir. To reinforce each stage of the automatic insertion area, at the end of each stage, a person was had as a final inspection of each stage. This entails more staff with an extra expense for the evaluated industry, but once this problematic situation is controlled, these personnel used for this extra activity, this inspection stage was eliminated and people changed activity. In the reworking, garbage of electronic components and damaged electronic boards where a part of the electronic boards material was generated and these, could be recovered.

Evaluation of damaged materials

The damaged materials were accumulated in the areas of reservoir activities, where a space not considered in logistics operations was used before the activities of the automatic insertion area initiated. This originated that contamination of electronic components and electronic boards will be generated, being a problem of contamination. Once it is finished again replacement activity, this material was made to an area of the electronic industry analyzed, and exposed outdoors and in soil without any construction, causing a possible soil contamination. In the reworking activities, were used welding irons to eliminate the welding of electronic components inserted into electronic boards, this being a risk to the occupational health of workers in this company, causing economic losses, by an electronic waste, and is represented in figure 6.
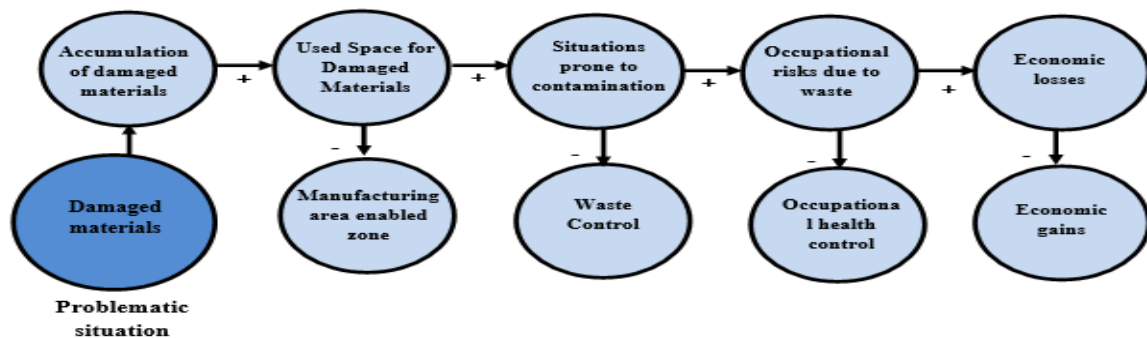

Fig. 6.Analysis of Environmental Impact by generation of waste of electronic components in electronics industry

Based on the evaluation, as shown in Figure 6, a solution proposal was made, analyzing and identifying the types of electronic garbage (electronic components, electronic boards and remote welding). In addition, the features of electronic garbage, recycling and reuse methods were evaluated, using the electronic components and electronic boards that could be recovered, for the care of the environment, being represented in Figure 7.
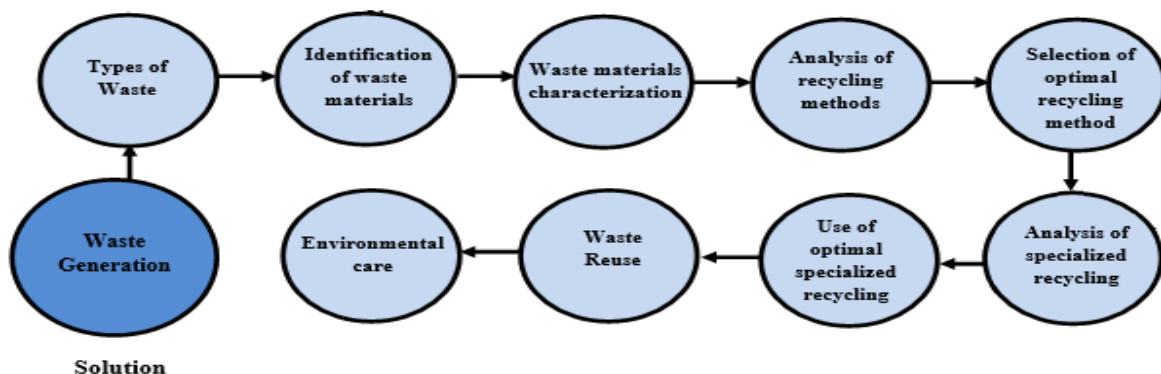

Fig. 7.Proposal for a solution to the generation of waste of electronic components and electronic boards

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Analysis of productivity

The triple relationship between lean manufacturing, sustainable manufacturing and productivity was evaluated with LM tools (such as Ishikawa diagram, Pareto diagram and control chart); and SM (reduction, recycling and reuse methods). In addition, production indices, quality, defective products (generated and recovered), with periods of extra time and economic losses from 2018 to 2019 were analyzed. With this analysis, relevant information was obtained with which the first six months of 2018 were observed. During the development of the research, production and quality indices lower than those predicted in a strategic logistics plan. The estimated production quantity was 10,000 manufactured products and 95% quality. As the investigation progressed, the production and quality indices, as well as defective products (generated and recovered), were improving, without reaching the levels estimated in the logistics plan at the beginning of the production period. This was due to the application of continuous improvement, which helped to improve the working conditions of the workers and the adaptation of new systems, equipment and industrial machinery, being an important factor in their operational performance and with it the increases in the production and quality indexes, and with it the productivity levels. This is illustrated in tables 1 and 2. With this analysis, the relationship between the BF, SM and productivity is described to determine quickly and efficiently, with the objective of obtaining descriptive models that link the aforementioned triple relationship, with which Productivity indices can be measured more accurately, which seems to every industry in the world as a relevant factor for meeting production goals and meeting customers to be a competitive company at the regional, national and global levels. Tables 1 and 2 show the aforementioned, illustrating the differences in quantities and percentages of evaluated factors and achieving about in each month after the seventh month of the investigation (July 2018), to the indexes proposed in the logistics area at the beginning of each manufactured product. In table 2, levels of lower risk of economic losses are observed, starting a stage to achieve economic gains from 2020 and for future manufacturing periods in the evaluated electronics industry. With this investigation, can be reach in 2021, the levels of production and quality mentioned above.

\Table- I: Analysis of productivity in the automatic insertion area of electronic industry (2018)

Factors Months	Production, Qty	Defects, Qty	Defects, %	Quality, %,	Recovered products, Qty	Recovered products, %	Overtime, Qty	Waste, kg	Economic losses, %
January	3856	788	20	79.6	499	63	88	147	18
February	4111	801	19	80.5	534	67	95	161	21
March	4345	834	19	80.8	588	71	104	179	25
April	4689	936	20	80.0	613	65	117	193	27
May	4861	998	21	79.5	654	66	133	209	31
June	5234	1012	19	80.7	703	69	147	216	36
July	5492	1078	20	80.4	744	69	127	188	27
August	5788	1103	19	80.9	793	72	106	163	22
September	5435	1055	19	80.6	801	76	91	148	19
October	5103	1007	20	80.3	775	77	76	129	15
November	4678	922	20	80.3	707	77	62	103	14
December	4236	869	21	79.5	684	79	58	88	12

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Table- II: Analysis of productivity in the automatic insertion area of electronic industry (2019)

Factors / Months	Production, Qty	Defects, Qty	Defects, %	Quality, %,	Recovered products, Qty	Recovered products, %	Overtime, Qty	Waste, kg	Economic losses, %
January	4143	401	10	90	321	80	45	59	7
February	4456	387	9	91	308	80	44	53	6
March	4983	428	9	91	347	81	42	58	8
April	5233	444	8	92	365	82	40	52	8
May	5590	489	9	91	399	82	44	59	6
June	5762	504	9	91	404	80	47	64	8
July	5935	567	10	90	444	78	41	61	9
August	6133	588	10	90	476	81	47	58	7
September	5895	469	8	92	372	79	46	59	8
October	5422	477	9	91	386		43	63	6
November	4877	446	9	91	354	79	45	69	5
December	4566	412	9	91	332	81	41	55	7

Analysis of soils around the electronics industry

The lack or environmental awareness in people of some companies, causes some deterioration of the ecosystems and then can disappears some species of animals and plants and can originates the climate change. All electronic garbage dumped by industries around of these type of companies, are going to stop, one way or another to aquatic and soils of ecosystems, and these can be directly, as seen in the images of this study, and indirectly, which companies or industries throw their waste to the ground, where in the rainy seasons the chemical substances are thrown very far from companies. This is represented in figure 8. There permissible limits worldwide that refer to the concentrations of substances discharged by the electronics industry, where most people can be exposed without adverse health effects, as the industrial industries of the electronic sector, installed in the Mexicali city.
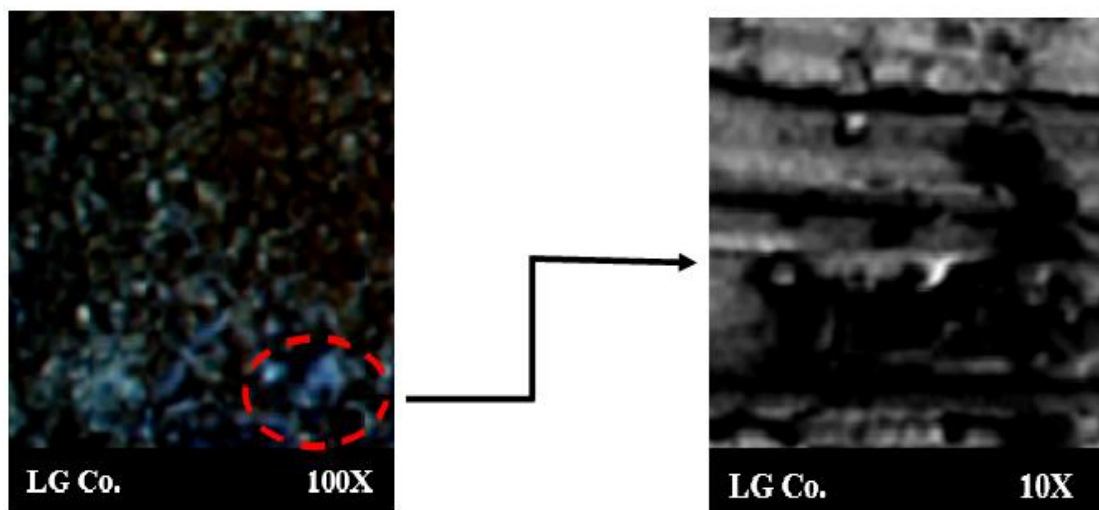

Fig. 8.Evaluation of the negative effect in population and ecosystems next to an electronic industry in Mexicali in the summer period in 2018 in company 1 as: (a) a correlation analysis of climatic and pollution factors with respiratory diseases, (b) chemical substance discharged in soil near of an industry evaluated and (c) SEM analysis.

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III. CONCLUSIONS

This investigation arose from the need to evaluate the relation of lean manufacturing and sustainable manufacturing, with continuous improvement tools, due to the great presence of waste defects of electronic components and electronic boards, generated by the improper methods of manufacturing. This was developed due to the fact that statistics from two years of evaluation of an electronic industry installed in the city of Mexicali with 750 workers, presented a large amount of defective products and with that waste, and was difficult to recovering the damaged materials, decreasing the productivity and quality indices. Due to the occurrence of this event, the company presented economic losses. In this industrial company there was a lack of control due to not having applied lean manufacturing methods and sustainable manufacturing, analyzing the indicators of productivity, production and quality and the impact on the interior environment of the evaluated company and the population that lives in its surroundings. This study was prepared to reduce the waste materials and increase the productivity and quality indices, with achieving with this an increase of the competitiveness of the evaluated electronics industry. This was through new strategies that allowed, as far as possible, to develop improvements in its industrial processes, as well as reduce the negative impact on the environment by the waste generated in this industrial company, considering the eight types of waste, which are explained later. It is concluded that with the support of the schematic diagrams, the industrial process was improved and therefore, the defective products were reduced, and with it the productivity and quality indices were increased, to obtain economic gains.

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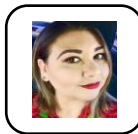
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He has papers related to "Lean Manufacturing", "Six Sigma" and "ergonomics and occupational health", has participation in investigations of applying technologies in Ergonomics,
Anthropometrical and Biomechanics area with tracking sensors, visual processing and health more Industrial Engineering. Is an expert in Ergonomics topics with investigations made in manufacturing processes of industries established in Mexicali, evaluating some methods and techniques to improve the work conditions of workers, and working with Notch sensors in some parts of body of persons to measure the anthropometric characteristics. His studies are of evaluations of characteristics of movements, when workers make the functions in industrial processes. Also, he has participated in investigations to measure the velocity of steps of manufacturing processes and related with the abilities of workers to avoid any type health symptoms in some parts of body of operative personnel in some type of industries located in Mexicali.

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