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SUMMARY

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RESEARCH ARTICLE OPEN ACCESS

AUTOMATION ENGINEERING SERVICE FOR CORN STEEPING AND WET MILLING PROCESSES, IN FACTORY OF GLUCOSE AND CORN DERIVATIVES (GYDEMA): CIENFUEGOS, CUBA

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ABSTRACT

The factory of glucose and corn derivatives of Cienfuegos is one of the most important factories of this city's industrial pole. As part of the modernization of processes on this factory, an automation engineering service was carried out by the CEDAI Enterprise of Cienfuegos. The main goal of this service was to implement a control system that will optimize steeping and wet milling processes, improve the process operation, increase the productive capacity of these areas as well as the product quality. To do so, many tasks were executed, it was necessary to replace the obsolete equipment, as well as pneumatic equipment, and the incorporation of new technologies for process control. Likewise, the development and implementation of a SCADA for steeping process. On the other hand, the wet milling process was provided with a modern MCC, equipped with advanced technology to this end, which includes a PROFINET network for motor control and using SIEMENS technology. Additionally, an HMI based SCADA was implemented to control the wet milling process. With the final application of this service, centralized control of pumps and motors of these processes was achieved, as well as supervise the status of the corresponding equipment and continuously monitoring the process variables through simple interfaces, easy to use and interact. Thus far, the developed control systems has been operating for more than two years and its implementation was a step forward for the technological upgrade of the factory, improving consumption rates, saving energy and increasing the production rates, as well as the quality of the product.

Keywords: Industrial Automation, Control System, SCADA, Corn Wet Milling.

I. INTRODUCTION

The factory of glucose and corn derivatives (GyDeMa) is located on Cienfuegos province, in Cuba. It is intended to obtain corn starch and glucose, which are essential to manufacture a lot of either alimentary or cosmetic products on the region.

This factory has many working years and a remarkable technological slowdown, because of the lack of an adequate maintenance plan for the existent equipment and a nonexistent investment plan on new technologies to improve the process.

This industrial process is divided into many areas such as: cleaning, weighing, steeping, wet milling, fiber washing, pressing and drying, just to mention a few. This paper focuses on steeping and wet milling processes.

In order to achieve higher production levels and increase the quality of the final product, guaranteeing the technological update of the factory and facilitating the operation of the process, the Integral Automation Enterprise (CEDAI) of Cienfuegos carries out an automation engineering service.

The given service had three fundamental stages, such as replacing obsolete and defective equipment; to incorporate new equipment with modern technologies for process control (sensors for measuring process variables and equipment status, modern Motor Control Center (MCC) with intelligent devices for motor protection and control; and finally, the implementation of Supervisory Control and Data Acquisition (SCADA) for process control.

I.1 PROBLEM SITUATION

The control equipment in both process areas was truly obsolete and the lack of an automated process brought with it many consequences like inefficiency.

On both areas, there was no control over motors and pumps, command and signaling units as well as protection and control devices were defective and damaged. As described, the milling process is basically constituted by the control of motors and pumps, so this problem should be resolved with priority.

In contrast, specifically on Steeping Area, pneumatic sanitary valves and the equipment to control them was obsolete and not functional; process temperatures were not taken continuously and correctly, so the steeping process tended to fail or get unwanted results.

To solve these problems and guaranteeing the technological update of the plant, on each process different automation methods were used, but always using the Programmable Logic Controller (PLC) and Human Machine Interface (HMI) / SCADA architecture for control systems.

II. DEVELOPMENT

Steeping and wet milling of corn are simple processes, however, the results obtained at the GyDeMa factory were not adequate due to the technological obsolescence of the equipment.

For a better understanding of the work performed, a description of the technological process must be made.

II.1 DESCRIPTION OF CORN STEEPING AND WET MILLING TECHNOLOGICAL PROCESSES

Once the corn is received at the factory by trucks, a cleaning process is performed using a cleaning system with de-dusters, vibration screens, elevators and sieves, in order to remove cobs, dust and foreign materials. Then, it is weighted and conveyed to the predefined SS tank for steeping. The quantity of corn to be steeped is controlled by the weighing system (approximately 30 Tm per tank).

The SS steeping tank is previously prepared for the process. It is deeply cleaned and half filled with sulfurous acid (H_2SO_3). This substance is the result of irrigating water over the fumes of burning sulfur (S), which is frequently employed as food preservative and fungicide, preventing excessive bacterial growth. [1]

When the predefined amount of corn is achieved, the SS tank is fulfilled then on a mixture of sulfurous acid and fresh water, to completely cover up the grains of corn. At this point, the SS tank is ready to start the steeping process, where the corn soaks at 50-52 degrees Celsius, on a recirculation cycle inside the SS tank. To do so, motors, pumps, temperature sensors and pneumatic sanitary valves are used.

The steep process takes over 40-60 hours, depending of corn, and at this point the corn has swelled and softened, ready for wet milling. Then, the SS steeping tank is drained out and the corn is carried to the Wet Milling Area. [2]

The wet milling process has several sub-stages. In the corn wet milling process, the corn kernel is separated into its component parts, and those parts are then further subdivided and refined. [3]

In this process the mechanical separation of the corn kernel components (fibers, germ and starch) occur. Initially, the corn passes through a stone separator and then added into the first mill, where water is poured to moisten the milling process.

The three mills employed on the complete process are cog wheeled mills; the first one, particularly, performs a coarsely ground, guaranteeing the braking of the grain without damaging the germ. It is necessary to not break the germ, since it has a high content of oil [3] and would cause disturbances in the following stages of the process.

Taking advantage of the properties of the germ, which floats over the slurry obtained during the milling process, it is separated using centripetal force on stainless steel vats with agitator. This process is repeated for a second time, but using fine mills, obtaining fibers and a suspension of starch.

The germ, fibers and the suspension of starch are independently washed using rotary screens to catch any residual starch [2].

Once the milling process has finished, the suspension of starch is submitted to other processes like starch-gluten separation, and starch drying, in order to obtain starch as final product.

II.2 AUTOMATION FOR STEEPING AND WET MILLING PROCESSES

II.2.1 Programmable Logic Controller (PLC)

A Programmable Logic Controller (PLC), also referred to as programmable controller, is the name given to a type of computer commonly used in commercial and industrial control applications. PLCs monitor inputs and other variable values, make decisions based on a stored program, and control outputs to automate a process or machine. [4]

In accordance with [5], the controller governs the output signals according to the program control logic previously stored in memory on the central processing unit (CPU) of the PLC, based on the state of the input signals. This program is inserted into the PLC through the programming unit, which also allows additional functions such as program debugging, simulation, monitoring, PLC control and more.

II.2.2 Human Machine Interface (HMI)

Human Machine Interface or HMI are devices used in industry to control and monitor machines. They may include information like temperature, pressure, process steps, and material counts. [6]

HMIs use special software so engineers can program them correctly. The software allows the engineer to design what the operator will actually see on the screen, what they can monitor on the screen, and how the operator can manipulate the machine. Engineers can program an HMI to perform almost any function that can be controlled or information that can be monitored by a PLC. HMIs and PLCs work together to monitor and control the machine using an industrial network. [6].

II.2.3 Automation of steeping process

In this area, the automation engineering service was executed using the existing equipment in CEDAI warehouse. So two controllers were installed, given the limited number of expansion modules they support and the huge amount of signals to treat. One controller manages motors, pumps and pneumatic sanitary valves, and a second controller manages process temperature signals.

There was developed and implemented a SCADA, to run in the control station, using a high performance personal computer (PC).

For motors and pumps, all command and signaling units, as well as protection and control devices were replaced with new equipment and also, integrated to the new control system with control relays. Likewise, two temperature sensors were installed per tank, one at the top, right on the feeding water pipe of the SS tank, and other at the bottom. Pneumatic sanitary valves were replaced for new ones with an indicator unit for positioning; for control pneumatic solenoid valves were installed, converting electrical signals into pneumatic functions.

Both controllers are connected to a PPI/MPI network and share information with the SCADA. The rest of the signals are independently wired to controllers; no fieldbus was used, as presented on Figure 1.

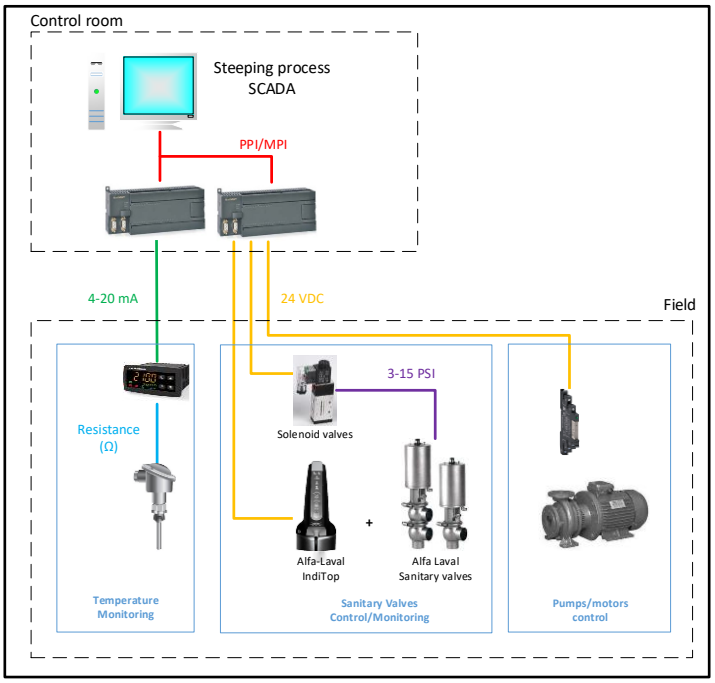

Figure 1: Control system for steeping process.
Source: Authors, (2020).

II.2.4 Automation of wet milling process

For wet milling process automation, a new control system based on SIEMENS technology and PROFINET communication was developed and implemented, as exposed on Figure 2.

To this end, a complete substitution of the conventional Motor Control Center (MCC) and the obsolete control system was performed. The new MCCs, were equipped with modern switching and short-circuit protection mechanisms, as well as a power monitoring system with SENTRON components. Also, to control motors and pumps, devices like: SIRIUS Motor Management and Control Device (SIMOCODE PRO) and SIRIUS 3RW44 Soft Starters were installed. According to [7], SIMOCODE pro links the higher-level automation system and the motor feeder intelligently.

The SIRIUS 3RW44 Soft Starter, on the other hand, is an electronic motor control device for optimized starting and stopping of 3-phase asynchronous motors. [8].

For process control, SIEMENS S7-1200 controllers were installed. Because of their compact design, flexible configuration, and powerful instruction set, these controllers provide the flexibility and power to control a wide variety of devices on a wide variety of applications. [9].

Additionally, a SCADA based on HMI was implemented on a SIMATIC HMI TP1500 Basic PN panel, in order to actuate process motors and pumps.

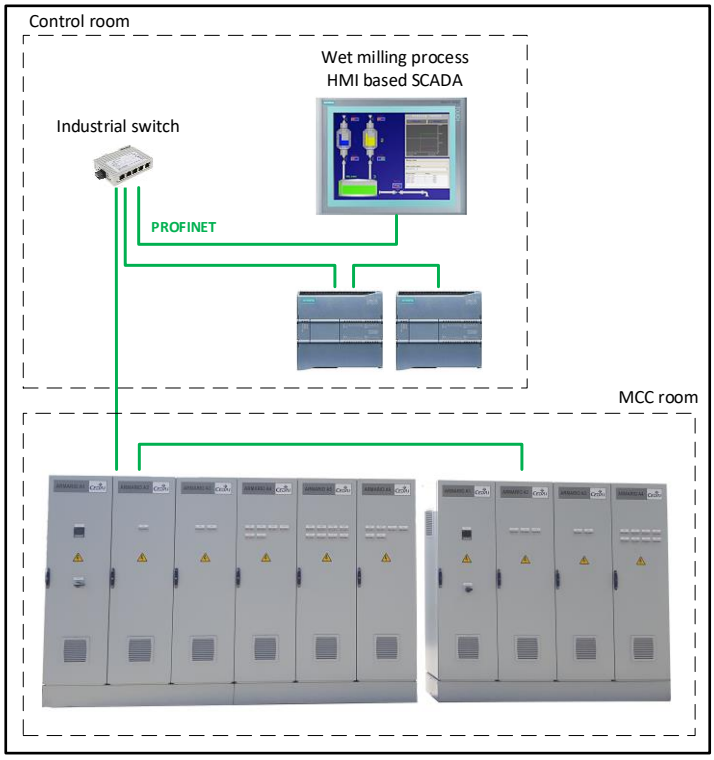

Figure 2: Control system for wet milling process.
Source: Authors, (2020).

Besides, Static Var Compensators (SVC) are devices that can quickly and reliably control line voltages [10], for this purpose, they were incorporated to the main power supply network.

II.3 AUTOMATION TECHNOLOGY

II.3.1 Control system for steeping process

On Steeping Area, UniMAT controllers - CPU 226 - were installed with expansion modules of the same company (Figure 3). UniMAT CPU 226 is manufactured in China and it's similar to SIEMENS S7-200 controller.

Also, guarantees signal processing, safe and correct operation of all the programmed sequences and logic algorithms. As well, it has the following features:

• CPU 226 DC/DC/DC, power 24 VDC, program memory size of 24 KB and 10 KB of data memory, 24 digital inputs, 16 digital outputs, 2 PPI/MPI ports and up to seven expansion modules. [11]

• UniMAT expansion modules used: EM223 - 32 digital inputs module, EM222 – 32 digital outputs module, EM231 – 8 analog inputs module.

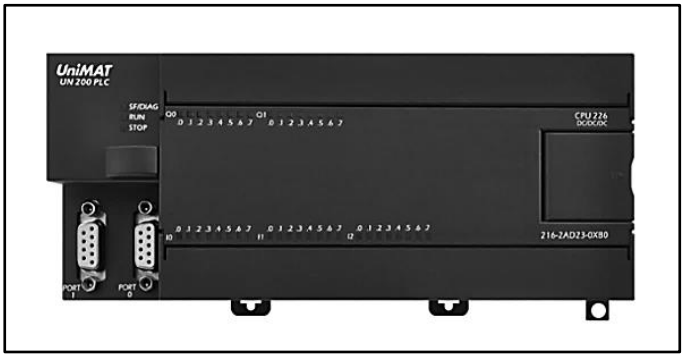

Figure 3: UniMat CPU 226 DC/DC/DC.
Source: [11].

Besides, control system was also integrated by the following elements:

• TB11-6 (Figure 4). RTDs from Thermibel manufacturer, SC-TB series screw-in probes with sheathed, non-replaceable sensing element and DIN B connection head, with Pt100 sensing element, sliding connector and three wires for signal output.

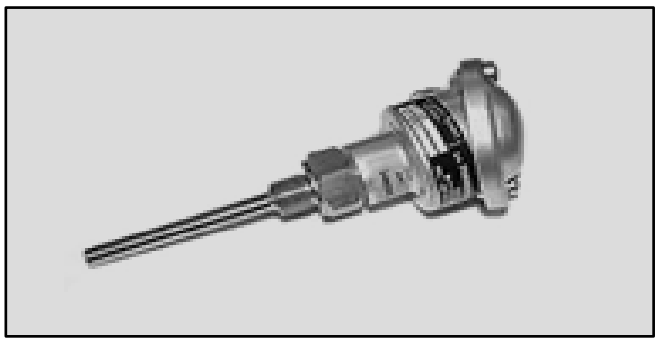

Figure 4: TB11-6 Thermibel RTD.
Source: Authors, (2020).

• Temperature controller programmer KR3 (Figure 5), from ASCON TECNOLOGIC manufacturer. These devices were used as transducers, receiving the resistance signal from the RTDs, screening the temperature value and transmitting to UniMat controllers over 4-20mA signal.

Figure 5: Temperature controller programmer KR3.
Source: [13].

• IndiTop (Figure 6), is an indicator unit for sanitary valves positioning from Alfa Laval manufacturer. IndiTop is designed to be a part of the PLC's Input/Output (I/O) system, and it's attached to sanitary valves. Positioning is firstly programed on Setpoint 1 or 2, and then matched to controller's logic [13].

Figure 6: Alfa Laval IndiTop.
Source: [13].

II.3.2 Control system for wet milling process

The devices that compose the control system have the following features:

• SIMATIC S7-1200, CPU 1214C AC/DC/relay (Figure 7): it's a compact CPU with 1 PROFINET port and an onboard inputs/outputs distribution: 14 digital inputs (24 VDC), 10 digital outputs (relay) and 2 analog inputs (0-10 VDC). Power supply: 85-264 VAC and program/data memory of 100 KB. Up to 16 connectable IO devices. Article number: 6ES7214-1BG40-0XB0 [14].

Figure 7: SIMATIC S7-1200, CPU 1214C AC/DC/relay.
Source: [15].

• SIMATIC S7-1200, CPU 1215C AC/DC/relay (Figure 8): it's a compact CPU with 2 PROFINET ports and an onboard inputs/outputs distribution: 14 digital inputs (24 VDC), 10 digital outputs (relay), 2 analog inputs (0-10 VDC) and 2 analog outputs (0-20 mA). Power supply: 85-264 VAC and program/data memory of 125 KB. Up to 16 connectable IO devices. Article number: 6ES7215-1BG40-0XB0 [16].

Figure 8: SIMATIC S7-1200, CPU 1215C AC/DC/relay.
Source: [17].

• SIMATIC HMI TP1500 Basic PN panel (Figure 9); it has a 15'' TFT display, with touch operation and one PROFINET interface [18].

Figure 9: SIMATIC HMI TP1500 Basic color PN.
Source: [18].

• SIMOCODE PRO, according to [7] is a flexible and modular motor management system for motors with constant speeds in low-voltage applications. It optimizes the link between the control system and the motor feeder, increases plant availability and allows significant savings to be made during installation, commissioning, operation and maintenance. In this case, SIMOCODE PRO V PN were installed (Figure 10), which incorporates 2 PROFINET ports.

Figure 10: SIMOCODE PRO V PN.
Source: [19].

• SIRIUS 3RW44 Soft Starter (Figure 11), is an alternative for star-delta starters and frequency converters; in this case, they were used on motors and pumps without speed control, where no particularly high starting torque or no startup with close to nominal current was required [20].

Their major benefits are smooth starting and stopping, uninterrupted changeover without current peaks that would stress the power supply, and their compact dimensions [20].

Figure 11: SIRIUS Soft Starter 3RW44.
Source: [8].

• SENTRON PAC 3200 (Figure 12), it is a power monitoring device for displaying all the relevant system parameters in low-voltage power distribution [21].

Figure 12: SENTRON PAC 3200.
Source: [22].

II.4 PROGRAMMING SOFTWARES

To program all the previously mentioned devices, many programming softwares were used:

• STEP 7 – Micro/WIN software (SIEMENS), for programming UniMat CPU 226. This programming package provides a user-friendly environment to develop, edit, and monitor the logic needed for control applications. It also offers a variety of tools and features for designing, implementing, and debugging programs for S7-200 controller's family [23].

• SIMATIC WinCC v7.0 software (SIEMENS), to develop the SCADA for the steeping process. SIMATIC WinCC is an HMI software program for the operator control and monitoring of automated processes in the machine-manufacturing and plant-engineering industries. This software has high functionalities, high efficiency and it's easy-to-use [24].

• TIA Portal V14 SP1 (SIEMENS) to develop the control system programming each device on wet milling area. TIA Portal, is the Totally Integrated Automation Portal which is a complete software package that includes for example: STEP 7, WinCC and SIMOCODE ES.

STEP 7 (TIA Portal) is the engineering software to configure the SIMATIC S7-1200, S7-1500, S7-300/400 and WinAC. STEP 7 provides a user-friendly environment to develop, edit, and monitor the logic needed to control applications [25]. In this case, for programming the S7-1200 devices STEP 7 Professional edition was used, as part of TIA Portal V14 SP1.

On the other hand, and in accordance with, [25], WinCC (TIA Portal) is an engineering software for configuring SIMATIC Panels, SIMATIC Industrial PCs, and Standard PCs with visualization software. To program and configure the SIMATIC HMI TP1500 Basic color PN, WinCC Professional edition was used, as part of TIA Portal V14 SP1.

Lastly, SIMOCODE ES V14 (TIA Portal), is the central software package for the configuration, commissioning, operation, and diagnosis of SIMOCODE pro [26].

III. RESULTS

Once the mounting and starting up stages ended, the automation engineering service obtained satisfactory results.

For steeping process, from the implemented SCADA system, operators can have full control over the process from the control room, monitoring process temperatures, setting and

monitoring the sanitary valves position, managing warnings and alarms and controlling motors and pumps, using control faceplates and interactive menus to shift control screens. This SCADA (Figure 13) has a friendly graphical interface which allows comfortable interaction with the user, allowing easy operation and fast learning of the system.

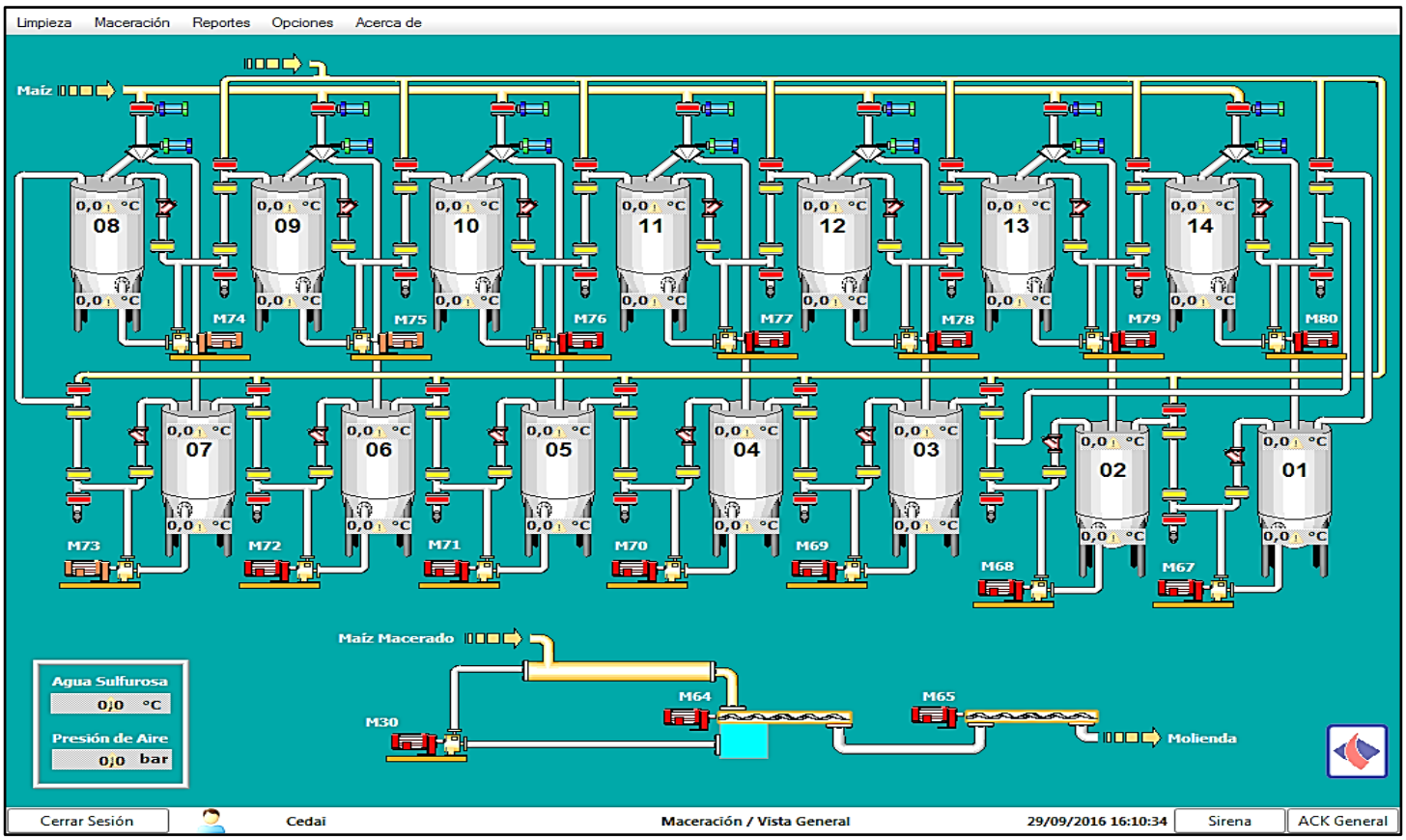

Figure 13: SCADA for seeping process.
Source: Authors, (2020).

On the other hand, for wet milling process, with the HMI based SCADA, centralized control of pumps and motors was achieved, where it is possible to manually or automatically control the process following the operation sequence through work-groups. Also, it is possible to visualize the status of the equipment (ready, failing, running, disabled, starting) and the behavior of its electrical parameters; with monitoring, management and information on the nature of warnings and alarms; all through a simple interface, easy to use and interact (Figure 14).

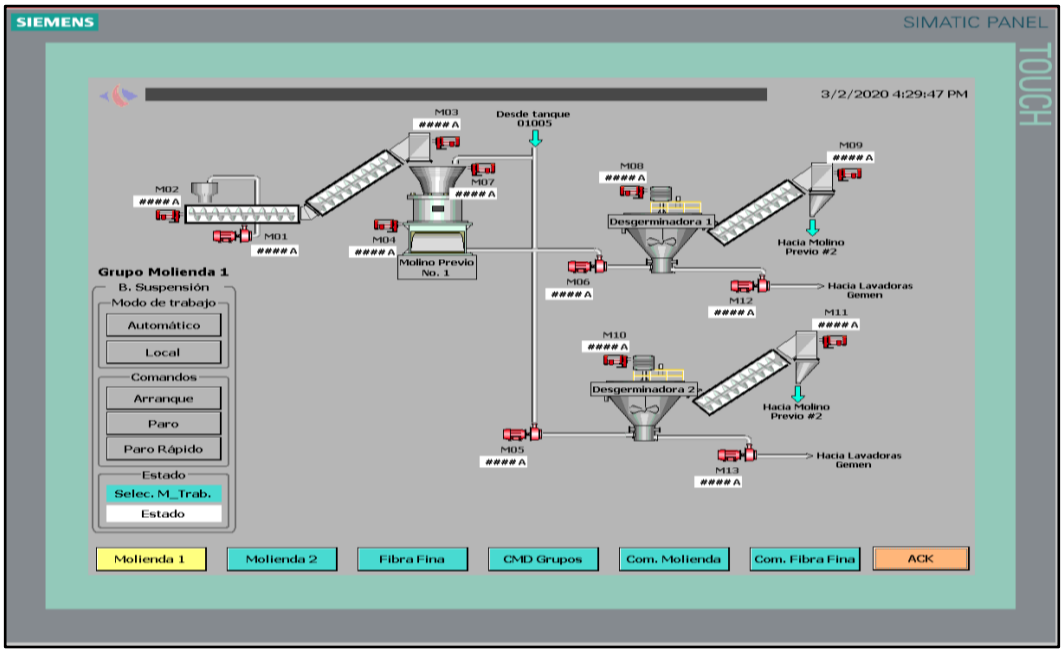

Figure 14: HMI based SCADA for wet milling process.
Source: Authors, (2020).

Figure 15: MCC room for wet milling process.
Source: Authors, (2020).

Also, both implemented control systems, despite being different, brought a significant economic impact to production levels, product quality and efficiency. All these indicators were increased considerably and, according to the collected production data, the production levels augmented three times the initial value after executing the automation engineering service.

IV. CONCLUSIONS

In this automation engineering service, control systems were meticulously developed and implemented, adjusted to the sequence operation of the processes, their control algorithms and operational needs, through modern technologies. All these actions contribute to the technological update of the factory.

With the implemented SCADAs, centralized monitoring and control of steeping and wet milling processes were achieved, facilitating processes operation through a friendly and easy-to-use environment.

The increased production levels obtained after the described automation engineering service was executed, establishes Automation as one of the most viable ways to optimize production processes.

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RESEARCH ARTICLE OPEN ACCESS

AN ANALYSIS OF USING A MIX OF CLAYEY MATERIALS AND CEMENT MORTAR IN SEALING MASONRY CRACKS

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ABSTRACT

This work presents results on the application of a crack treatment by using clayey material in cement mortar. In this way, it is analyzed the behavior of the material applied in the external pathologies of a residential property. Results are presented in order to explain all the stages of the methodology used here, as well as to display some features of the method such as the time of observation, an attribute determined after the application of the technique. From the results, it is observed that the evaluations are in good agreement with what was expected for the technique. Since the developed mortar presented good texture and resistance, it was proven that the material is suitable to be applied in engineering services. It is interesting to observe that the method achieved a good resistance, since in just seven days of healing it became higher compared to the reference trace. This feature is due to the way the trace is executed, since this procedure directly affects the results. Another important benefit obtained with the proposed method is related to the infiltrations, where all points have ceased and the pathologies did not reappear. It is emphasized that the observation was made for a period of one year, an appropriate time for the occurrence of new pathological manifestations. In addition, the new material was applied in the cracks of a fence wall located in a residence at Manaus, Amazonas. In this way, the occurrence of pathologies is probably related to the shrinkage in concrete. This process is due to the loss of volume that occurs in the cement mass, being related to the reduction of excess water from the mixture by the evaporation method. The main objective of using cement mortar is to eliminate this problem in the long-term maintenance, as it causes an aesthetic discomfort. Finally, the application of the method was proven to be suitable for the studied case, since we have observed a satisfactory result. Also, the method application had a low cost since it is derived from a natural material easily found in nature.

Keywords: Cement mortar, Clay, Masonry cracks.

I. INTRODUCTION

Cracks are pathologies that manifest in masonry walls as openings up to 0.5 mm [1]. Such anomalies can occur due to design flaws, materials and execution and it is important to analyze what are their main causes, as it is always a general concern when any component of a building fails to meet the minimum requirements for which it was designed. As explained by [2], if the possible causes of cracks are not properly diagnosed and remedied, they can turn into large cracks.

In this regard, these larger cracks are irregularities that affect the expected quality of the building, such as in water tightness, thermal and acoustic comfort, durability and even structural safety. These problems can be caused, according to [3], by: thermal movements, overload performance, foundation settlements, deformations of structural elements, chemical reactions in construction materials, among others. [4], states that cracking is a pathological manifestation that may indicate a dangerous state in which there is a lack of durability on the

construction, causing the building users to feel uncomfortable about the building security.

It is necessary to make an exact classification of the crack, regarding its origin, its dimensions and, above all, its severity, in order to identify the need to proceed to its treatment and the choice of the appropriate technique and materials for its repair [4].

According to [5], using clay is one of the oldest building techniques in the world, and also comprises one of the first materials to be used for this purpose. From the point of view of sustainability, the clay presents several advantages. Countless ancient civilizations have used different clay construction techniques. In addition, several of them were widely used during the colonization of Brazil, being left aside with the industrialization process. For [6] states that studies related to the application of clay with some type of additive are of great value, since they can enable the development of products with greater resistance and durability, in addition to reducing costs and environmental impacts.

The aforementioned material is present in several compositions of cement mortar. In this way, the use of metakaolin-like calcined clays as pozzolanic material for mortars and concrete has received considerable attention in recent years [7]. Also, the most used clays for the production of pozzolana are kaolinite, montmorillonite and illite [8].

This study analyzes the use of a clay mixture in the cement paste in order to treat cracks, infiltration and aesthetics problems, where one of the main points is to find positive results. Moreover, it is important to mention that a cement mortar with clay mixture can be applied in different areas of civil construction (e.g. glue for deep drainage pipes) [9].

Therefore, the present manuscript aims to verify if the above-mentioned technique presents positive results in the treatment of cracks by performing the following procedures: to examine the cause of the cracks in a sealing masonry, to test the durability and resistance of the applied mortar, to analyze the behavior of mortar and cracks for a period of one year, to verify the advantages and disadvantages of using clay, and to study the behavior of this material applied to the external cracks in a residential property built using non-structural sealing masonry. In short, we present all the stages, procedures and their results after one year of applying the technique.

II. METHODOLOGY

This study was conducted performing the steps described below and detailed in the subsections.

The first one consisted of a bibliographic research on the properties of clay, as well as the advantages and disadvantages of using it. As part of the first step, measurements of the strength of this material were obtained by carrying out a compression test in laboratory. Also, the addition of 20% and 30% of clay material was made to analyze whether mortar with a quantity greater than 10% would have the same behavior. From this perspective, it is emphasized that adding a quantity less than 10% is not the most appropriate, as shown in [9].

The second step was based on studying the causes of cracks on a residential property located in the city of Manaus, Amazonas.

At last, the third step consisted of studying and applying the cement mortar with clay in the pathologies. After this procedure, the behavior of the mortar started to be monitored. From this perspective, possible anomalies and infiltrations were also photo-recorded during the period of one year.

Then, the process of photo collection started in order to record and detail all stages of the methodology. Thus, from the above-mentioned steps, the possible cases of pathological manifestations were identified and presented.

II.1 GENERAL ASPECTS OF CLAY

The clay is a rock consisting essentially of a group of minerals called clay minerals [10]. For [11] states that this material is originated from the decomposition of rocks. In this way, the types of clay can be classified into primary, formed in the same location as the rocks, or secondary, formed by weathering.

The term *sensu lato* clay is used to designate a natural inorganic material of fine granulometry, which presents a plastic behavior when mixed to a certain amount of water. From a sedimentological-granulometric point of view, the clay fraction corresponds to the set of particles smaller than 2 μm or 4 μm [12]. According to [13], some other types of clay material are currently used:

• Kaolin: a clay consisting essentially of kaolinite with a very high refraction index;

• Bentonite: a residual clay resulting from the alteration of volcanic ashes or acidic tufts, with a very fine granulometry and variable color. It is emphasized that the bentonite, due to its properties such as plasticity, impermeability, resistance to compression, and low compressibility has also other applications in civil engineering (e.g. landfill cover, basin waterproofing) [14];

• Common clay: the most common type of clay in nature. This material is mainly used in the manufacture of low-cost ceramic products; and

• Fibrous clays: a type of clay composed of fibrous clay minerals belonging to the group of paligorsquite and sepiolite.

The clay used in this work was collected in a deep drainage construction, placed in the Japiim neighborhood at Manaus, Amazonas. It is emphasized that this site corresponds to the same source of clay described in [9]. In addition, the material used here is characterized as ordinary clay or red clay. In this way, the red clay is originated from physical and chemical weathering over rocks with a greater predominance of iron oxide, which gives rise to particles much smaller than grains of sand.

From that perspective, one of the predominant chemical components of the material used in this work is iron oxide. In civil construction, expanded clay is generally used in the mixture of light concrete due to its low density. In this context, the impermeability is also an important factor. Regarding the common clay, it is generally used for manufacture of ceramic products, but it is worth mentioning that there are two main types according to its use: pottery clay and brick clay [15].

II.2 ADVANTAGES AND DISADVANTAGES OF USING CLAY

According to [5], clay as a building material has certain advantages and disadvantages. In this context, the use of clay provides a healthy environment, since it is able to absorb and lose moisture faster than any other building material. Also, due to its thickness and density after molding, the clay reduces the transmission of noise, and when compared to other materials it is more economical than the industrial ones. It also provides low maintenance and long durability, because after being built and sealed the clay should not need maintenance for about 10 to 20 years. However, the disadvantages of using clay in civil

construction are related to the fact that it is not an impermeable material, so the contact with water must be avoid in order of prevent cracks occurrence.

Moreover, the employment of expanded clay as a coarse aggregate brings numerous benefits, such as thermal and acoustic comfort, also being considered as an economic and ecological solution in the use of concrete [16].

II.3 THEORETICAL ASPECTS OF BUILDING PATHOLOGIES

According to [17], cracks can be caused by several factors. Some of the most common causes are: excessive load on walls, temperature variations, retraction of blocks, and concrete elements.

The masonry cracks in buildings are a sign that something is wrong, which may compromise water tightness, sound insulation and even the building structure. Even though there are no risks in the structure, the cracks have a very negative aesthetics effect on the residents, and it is natural to them to demand the solution of the problem [19].

For [20] states that the openings are classified according to their thickness in: crack, large crack, disruption, slit, or breach. This classification is presented in Table 1:

Table 1: Classification of pathologies according to their openings.

Pathology	Opening (mm)
Crack	up to 0.5
Large crack	0.5 to 1.5
Disruption	1.5 to 5.0
Slit	5.0 to 10.0
Breach	> 10.0

Source: Adapted from [21].

According to [21], the pathologies can occur due to the human error during the design phase, the execution phase or even during the use phase. For instance, in a survey conducted in Belgium by Reygaerts, it was found that out of 1200 cases the most common causes of cracking were [22]:

• 35% corresponding to the movement of the reinforced concrete structure;
• 25% due to the thermal influence;
• 25% due to the hygrometric influence; and
• 15% due to the movement of the foundation.

According to the [23] DNIT 083/2006 standard, cracks and large cracks are specific and unavoidable phenomena of reinforced concrete that can occur in each of the three following phases: plastic phase, hardening phase and hardened concrete phase. These pathologies are generated by several factors, where one of the most recurrent is the retraction process. In this way, the retraction movement start by the loss of moisture in the coating at its early stages, causing the appearance of internal tensile stresses that are relieved through the crack's occurrence.

II.4 APPLICATION OF THE TECHNIQUE

A conventional one-floor residence was chosen to study and analyze the pathologies and the application of the developed mortar. The masonry wall is sealed and located outside the house, and already had certain anomalies along its entire length, such as cracks and infiltrations (Figure 1).

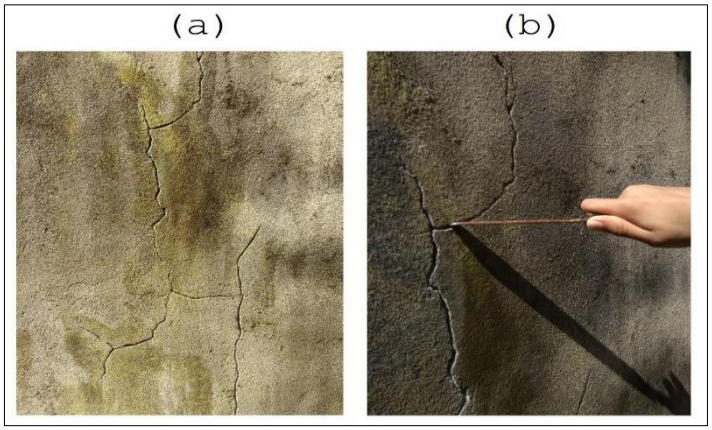

Figure 1: (a) Occurrence of cracks in the masonry wall, and (b) crack depth measurement.
Source: Authors, (2020).

From the above process, a set of photos was taken in order to present the treatment step by step, from its initial state to its finishing. Started the process of treating pathologies, the first step was to scarify it, as it is necessary to stimulate the opening of the fissure so that the applied product enters more easily and more efficiently (Figure 2).

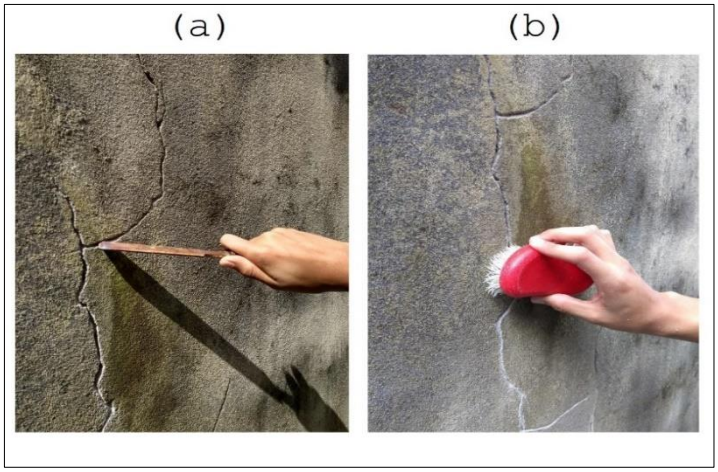

Figure 2: (a) Scarification process, and (b) surface cleaning step.
Source: Authors, (2020).

Then, the surface was cleaned with water, a fundamental procedure to remove the dirt and dust that remained on the surface after scarifying it. Thus, the product can have a good adhesion on the masonry (Figure 3).

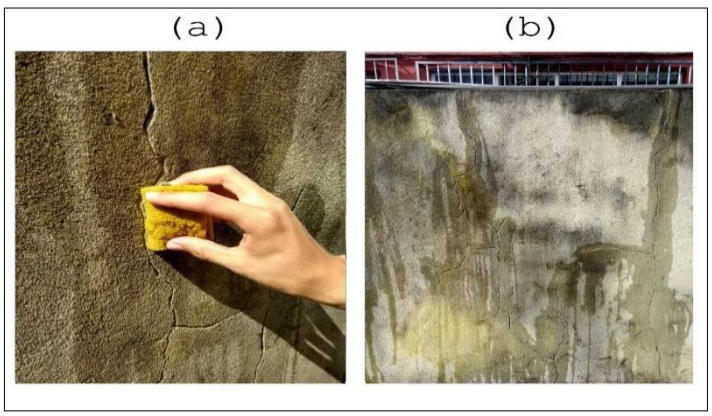

Figure 3: (a) Cleaning with water and sponge, and (b) cleaning completed.
Source: Authors, (2020).

Then, the mortar with ten percent of clay was applied. In order to facilitate the application, a silicone bag was used (Figure 4).

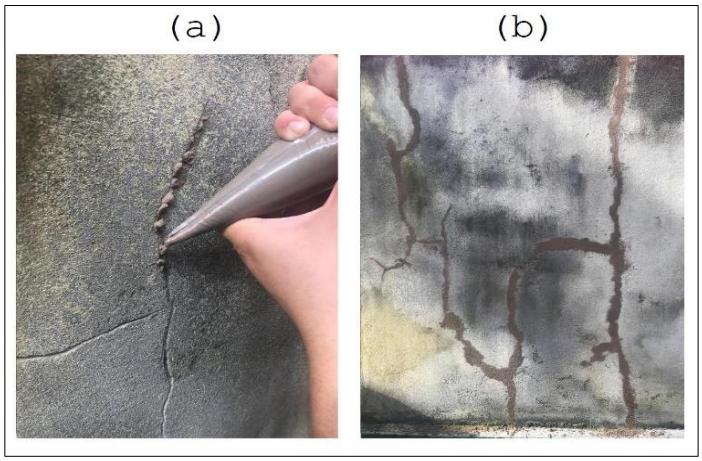

Figure 4: (a) Mortar application, and (b) completed application.
Source: Authors, (2020).

The wall was sanded three months after the mortar application. It is emphasized that this is the time necessary for the mortar behavior to be analyzed. Afterwards, the masonry was painted (Figures 5 and 6).

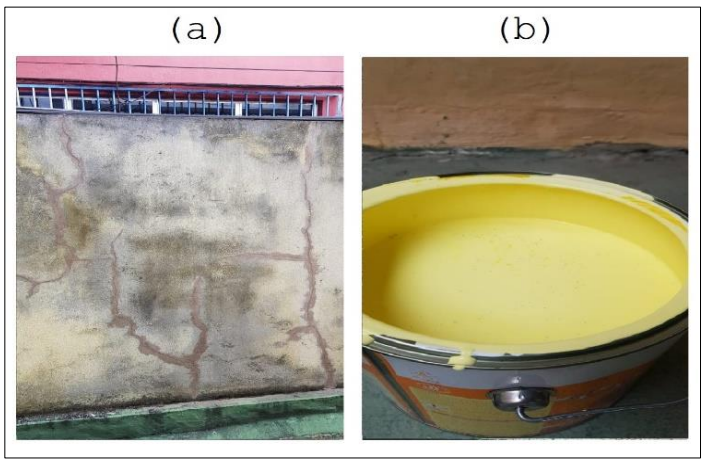

Figure 5: (a) After sanding, and (b) used ink - Iquine brand
Source: Authors, (2020).

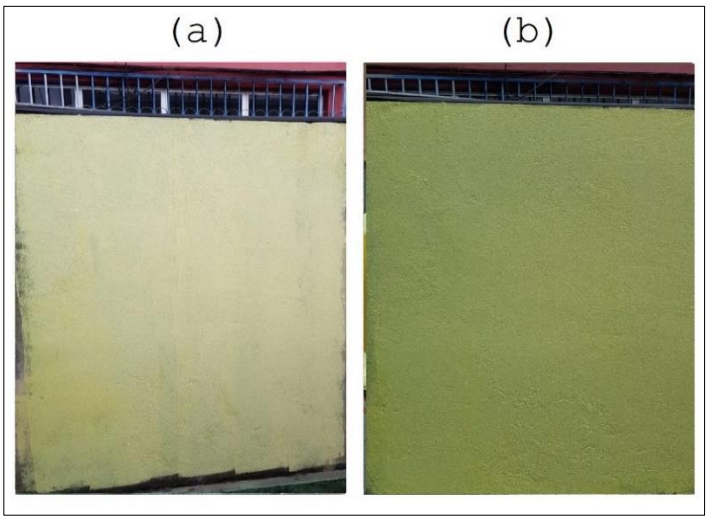

Figure 6: (a) First coat of paint, and (b) masonry finish.
Source: Authors, (2020).

After the service was completed, the behavior of pathologies in the masonry was observed for a period of one year.

II.5 STAGES FOR THE THREATMENT

The main steps necessary to carry out the treatment are summarized below:

- Scarification;
- Surface cleaning;
- Mortar application;
- Sanding;
- Masonry painting.

II.6 TESTS PERFORMED

According to [24], the main characteristic of concrete is its resistance to compression, which is determined by the test of specimens submitted to compression. This test also allows to obtain other characteristics of the material, such as the longitudinal strain module contained in NBR 6118/2010.

In this way, the compressive strength was performed over cylindrical specimens of 10 cm in diameter and 20 cm in height, or 5 cm in diameter and 10 cm in height. The test was based on increasing the tension gradually until the rupture of the material, according to NBR 5738/2015. In order to execute the procedure, the cylinder must be filled with concrete, in four layers. Each layer must receive 30 strokes with a metal rod, where the strokes must not touch the lower layer.

After compacting the last layer, the surface must be leveled with a spoon. After a 24-hour period, the removal of specimens from molds is performed. Each sample must be identified and must go immediately to wet curing, so that water reduction and alteration of the results in the resistance tests are avoided. The rupture of the specimens is usually performed in 7 and 28 days. After the days have passed, the specimens are taken to a press where their resistance to compression is measured. From the result of this test, it is verified whether the concrete reached the resistance determined in the project or not.

III. RESULTS AND DISCUSSION

This section presents the obtained results, as well as an analysis of the procedures based on their respective standards and technical instructions as it was obtained from DNIT Standard 083/2006 - Treatment of cracks and large cracks.

The studied masonry wall presented pathologies of less than 0.5 mm, being classified as cracks. The cause of these anomalies can be attributed to several factors, such as the retraction of the mortar, and also to the components used to build it. It is worth mentioning that after the construction of the original wall was completed, its structure collapsed. Thus, it was necessary to hire a new service to reform the wall. Certainly this second work presented problems of execution, which leads to be another probably cause for the development of these pathologies. Consequently, analyzing the results obtained after the application of the material on the sealing masonry, it was proven that the developed mortar performed well, since the cracks and infiltrations did not reappear after the procedure (Figure 7).

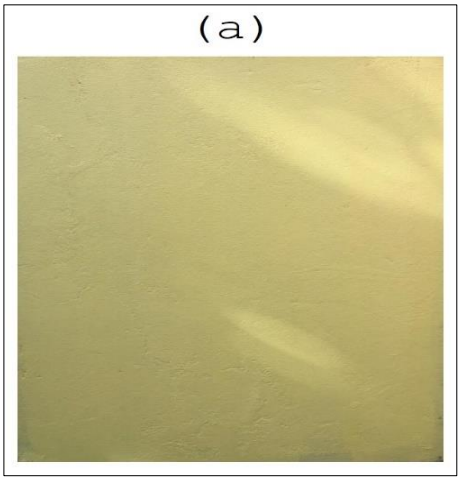

Figure 7: (a) Masonry wall after 1 year of observation.
Source: Authors, (2020).

The compressive strength test was performed at 7 and 28 days (Figure 8). The tests presented satisfactory results, since it was achieved the minimum fck, equal to 25 Mpa. For each dosage, two specimens were made with 10%, 20% and 30% of clay. These specimens were planned to be broken after 7 and 28 days, and the trace used as a reference was the same as used by [9] (Table 2).

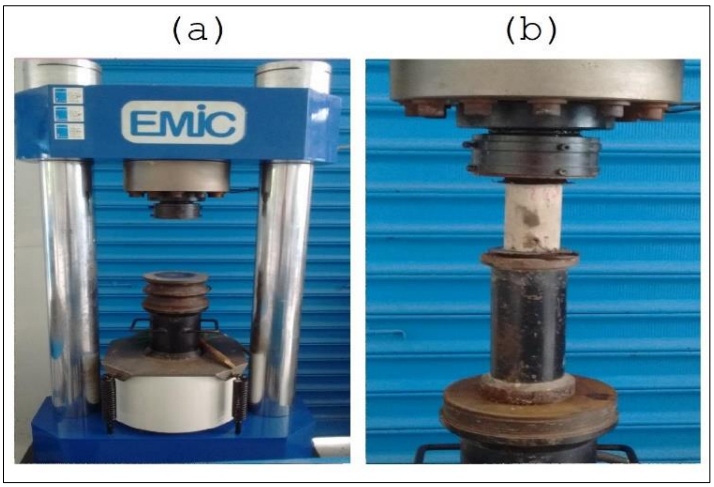

Figure 8: (a) Compression test press, and (b) developed specimen.
Source: Authors, (2020).

Table 2: Mass of the materials to be used on concrete, with 10% of clay.

Dosage - 10% Clay	
Material	Mass (Kg)
Water	0.25
Cement	1.00
Sand	0.50
Additive	7%
Clay	10%

Source: Authors, (2020).

According to the procedure found in [9] Menezes (2018), it was used an amount of clay with 8% and 10% in the mortar, since it was proven that the 10% dosage is more efficient. In the same way, a dosage was made by using the aforementioned trace, and two more dosages adding 20% and 30% in order to check whether mortar with a higher amount of clay material would have the same effect. In this way, after the compression test, the results of the resistance of each dosage after 7 days of curing were obtained (Figure 9).

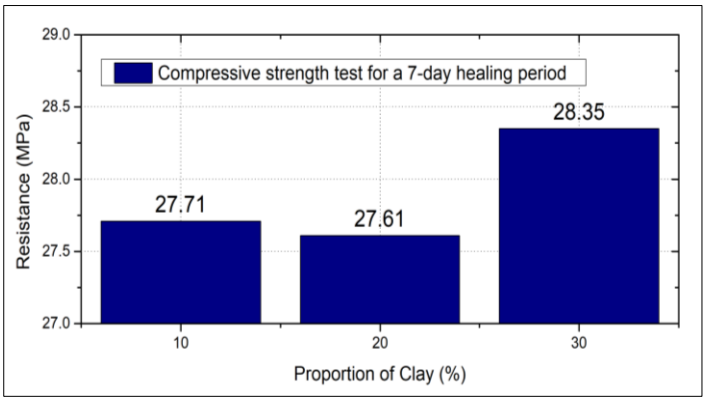

Figure 9: Mortar strength after 7 days of wet curing.
Source: Authors, (2020).

As mentioned above, it can be observed that in just 7 days of wet curing the mortar had a good result, reaching over 25Mpa in all dosages. Then, the specimens were tested with 28 days of wet curing, where it was obtained a very satisfactory result (Figure 10).

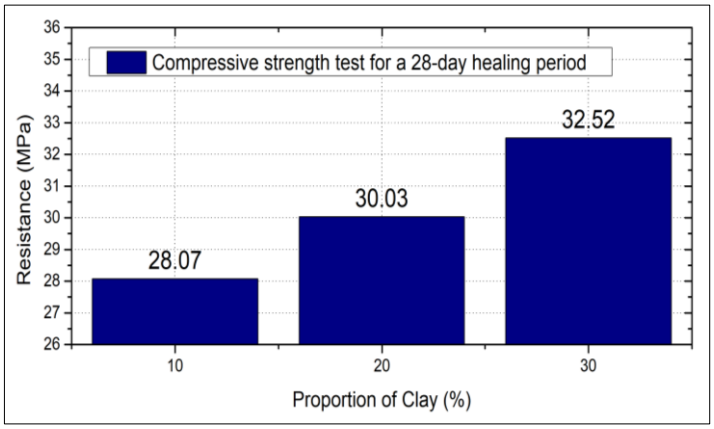

Figure 10: Mortar strength after 28 days of wet curing.
Source: Authors, (2020).

Therefore, comparing with the results of [9] (Table 3), it can be observed that the resistance data presented in this study (Table 4) proved to be superior. In this context, the Tables 3 and 4 present the compressive strength results regarding the dosage with 10% of clay. It is emphasized that only the additive was removed from the reference trace, as it is a material with a high economic cost. However, the other dosages were applied strictly.

Table 3: Compressive strength.

Days	**Compressive strength - CPII-s4-40 (MPa)**
7	7.96
14	17.65
28	28

Source: [9].

Table 4: Compressive strength with an average dosage of 10%.

Days	**Compressive strength - (MPa)**
7	27.71
28	28.4

Source: Authors, (2020).

In this regard, [9] states that the use of clay material together with a superplasticizer additive in mortar is highly effective, since this experiment presented good results and can contribute to future works in civil construction.

IV. CONCLUSIONS

The clay material can be used in several areas, such as in the manufacture of ceramics, in semiconductors for computer equipment, in the manufacture of bricks, manufacturing of cement and others. In ancient times, houses were made of clay, but since this material becomes plastic when in contact with water, it was necessary to use a sealant. It is interesting to mention that the clay material was widely used mainly due to its low economic cost, as well as due to its ease of being found in nature. After the tests and analyzes on the addition of clay in mortar, it was observed that both in terms of strength and consistency, the result was quite positive. Consequently, aiming to find a good solution for the treatment of cracks, it was observed that they did not reappear after the employment of the method. In this way, it is emphasized that they were observed and analyzed during a period of 1 year, as described in the methodology section. Starting from the concept of cracks as pathologies, it is emphasized that these anomalies can be caused by the concrete retraction process, and this action occurs due to the loss of water in the mortar. However, the anomalies were observed in the passive form, that is, it would not evolve in size or depth. It is worth mentioning that the infiltrations ceased, since the pathologies existing in the upper part of the masonry were treated with the developed mortar, what solved the problem. Taking into account what was previously mentioned, [9] only used the proportion of 10% of clay in the dosage. In this context, our study proved that it is possible to use an additional amount, such as 20% or 30%, as it does not interfere in its properties. In addition, the mortar with 30% of clay presented a good resistance to compression and good workability. The compression test was carried out at the Konkrex concrete plant (at Manaus, Amazonas) by using a hydraulic press, as shown in the methodology section.

The mortar used in this study proved to be more appropriate for the studied case that one used in [9]. A plausible explanation would be due to not using the additive in the dosage, the way in which the materials were mixed, as well as the density of the specimen. It is worth mentioning that there were no difficulties in applying the material on the masonry wall.

We concluded that this material is effective on treating masonry cracks, and can be also used as glue for deep pipes, confirming what was stated by [9]. In addition, mortar has good resistance to compression, and its use is more economically accessible when compared to acrylic or plastic sealants, canvas, waterproofing materials and other treatments, as it can be found in nature easily and due to its easy applicability. Finally, this material should be more explored as it can contribute even more in civil construction, since it presented good results.

V. ACKNOWLEDGMENTS

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RESEARCH ARTICLE OPEN ACCESS

DEVELOPING A LINEAR PROGRAMMING MODEL TO MAXIMIZE PROFIT WITH MINIMIZED LEAD TIME OF A COMPOSITE TEXTILE MILL

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ABSTRACT

In the competitive market of apparel manufacturing, lead time for production plays a significant role in the delivery of the produces impacting the entire supply chain. Nowadays, composite manufacturers are leaning towards delivering within the shortest possible time to retain customers in this competitive market. To meet this challenge, proper production planning either using the correct method or the appropriate tools is a prerequisite condition; otherwise, mills will inevitably suffer losses or fail to drain out the maximum possible profit from the produces and may also suffer from promoting more expenses rather than yielding revenues. This study deals with the development of a linear programming model in order to reduce the complexity of the scheduling problem of a Composite Textile Industry in pursuit of maximizing profit or minimizing production costs. The model is developed considering process segmentation, utilization of machines and other resources, with respect to lead time. Four different components of the lead time are derived and an excel solver is used in solving the model.

Keywords: Production planning, Lead Time, Profit Maximization, Linear Programming, Composite Factory.

I. INTRODUCTION

Production planning and control (PPC) plays a vital role in the RMG (Ready-made Garments) manufacturing industry. More effort put on planning stages can ensure profit maximization through waste reduction, lead time reduction, maximum utilization of current resources. In textile industry, production planning may vary order wise. After receiving the order, the initial stage of the process begins which is the production planning that includes production scheduling, manpower allocation, machine utilization, etc. and planning the monitoring activities to ensure that proper control measures are in place and the desired product is achieved with respect to quantity, quality, delivery schedule, and cost of manufacturing to meet the customer requirements within the specified time frame. Most companies are not aware of the applications of PPC in other areas such as marketing and scheduling. The advantage of production planning is to create a system along with a set of standard procedures for the effective conversion of raw materials, labor, and other inputs into the final product (garment).

A composite factory is a factory where all the processes of a garment product are accumulated. For instance, a knitting factory has many processes involved with the product such as knitting, dyeing, washing, all-over print, yarn dyeing, embroidery & sewing. Between these processes, we must follow several ladders which help us to attain the knitted garments to the customer with the ensuring quality. Bangladesh's export-oriented RMG sector is undergoing continual growth and it is currently showing huge potential to earn the highest amount of foreign currencies for the country. But as there are numerous numbers of competitors in this sector, the manufacturers are bound to control and lower down the lead time to produce the goods to live up to the competitive

market. To meet all the demands of the product and deliver it within the lead time depends highly on the production planning. To reduce the lead time for various processes maintaining higher profit is challenging. We must consider all the constraints for it and a linear model is developed considering all these constraints to maximize profit through the optimization of lead time for different processes.

II. LITERATURE REVIEW

Shorter lead time leads to a more responsive supply chain that has a higher percentage of on-time deliveries and more satisfied customers and less cost of inventory [1]. For proposed a formula for product lead time which is vital for production planning. Product Lead-Time is the total time, which is required to Design, Plan, Control, and Process a given product through the Plant. This is the sum of Design Time, Manufacturing Planning Time, Manufacturing Control Time, and Manufacturing Lead Time [2]. A five-step procedure is presented to determine the lead time scheduling of operations of orders. It showed that the accuracy of the lead time scheduling is dependent upon the estimation of the order operating time accuracy [3]. A stochastic optimization algorithm based on the perturbation analysis technique is proposed to optimize the stage lead-times in a two-stage stochastic system [4]. By shortening the lead time, safety stock can be lowered hence it can reduce the loss caused by stock out [5]. Julie has investigated the relationship between price, lead time and delay [6]. Many engineering optimization problems can also be considered as linear programming problems where all or some of the parameters involved are linguistic in nature [7]. The application of linear programming models is resource allocation to activities problems, and analysis of a multi-plant production system to determine whether or not certain plants should be shut down as a result of the high cost of production [8]. For [9] developed a linear programming model on the textile industry with linear interactive optimizer software to determine the optimal numbers of each of three of its products to maximize the overall profit of the organization. Lindo software was used to solve a linear integer programming model of a food production problem to maximize the profit [10]. Represented a linear programming model to maximize profit [10]. Integer Linear Programming Model is used to select the supplier considering multiple criteria [11]. For [12] developed a linear programming model in optimal production planning for ICI Pakistan using linear programming. The techniques of linear programming which point to maximize the profit generated from the production patterns of the ICI Pakistan. The fuzzy environment was considered to rank the best choice using TOPSIS [13]. The Multimodal linear transportation model was solved using an excel solver to minimize the total transportation cost [14].

III. METHODOLOGY

In a composite factory, product lead-time is the sum of four components, which are Design Time, Manufacturing Planning Time, Manufacturing Control Time, and Manufacturing Lead Time.

Total Lead Time

$$PLT = TPD + TMP + TMC + MLT \quad (1)$$

Where:
PLT = Product Lead Time
TPD = Product Design Time
TMP = Manufacturing Planning Time
TMC = Manufacturing Control Time
MLT = Manufacturing Lead Time

The Total Time of each phase is the amount of time in which, each function spends to complete its part of the job for a given product. This time largely depends on the kind of activities which each function needs to perform.

We mainly focus on Manufacturing Lead Time (MLT).

Table 1: Notation For an order of Q amount of knitting product.

P_O	=	Product Price per piece
MLT	=	T Days
R_F	=	The required amount of fabric
T_1	=	The time required for knitting
C_K	=	Knitting Capacity Kg/Day
P_K	=	Knitting Price Per Kg
T_2	=	The time required for dyeing
C_D	=	Dyeing capacity Kg/Day
P_D	=	Dyeing Price Per Kg
T_3	=	Time Required for Cutting
C_C	=	Cutting Capacity Kg/Day
P_C	=	Cutting Price Per Kg
T_4	=	The time required for printing
C_P	=	printing capacity
P_K	=	Printing Price Per Piece
T_5	=	The time required for sewing
C_S	=	Sewing capacity
P_S	=	Sewing Price piece
T_6	=	Time required for ironing & finishing
W_R	=	Worker Rate
$C_{I\&F}$	=	Ironing & Finishing Capacity
$P_{I\&F}$	=	Ironing & Finishing Price Per Piece

Source: Authors, (2020).

Objective Function:
Max Profit: Z= Product Quantity* Product Price- Product Making Cost- Labor Cost

$$\text{Max } Z = P_O * Q - (P_K * R_F + P_D * R_F + P_C * R_F + P_P * Q + P_S * Q + P_{I\&F} * Q) - (T_1 + T_2 + T_3 + T_4 + T_5 + T_6) * 24 * W_R$$

Subject To

$$R_F \leq T_1 * C_K$$
$$R_F \leq T_2 * C_D$$
$$R_F \leq T_3 * C_C$$
$$Q \leq T_4 * C_P$$
$$Q \leq T_5 * C_S$$
$$Q \leq T_6 * C_{I\&F}$$
$$T_1 + T_2 + T_3 + T_4 + T_5 + T_6 \leq T$$
$$T_{i=1,2,3,4,5,6} \geq 0$$

Table 2: Ordering Data.

Order Quantity	**Price per Unit ($)**
10000	$ 3.00

Source: Authors, (2020).

Our product is knitted top. Garments components are front, back, and sleeves and the lead time is 60 Days. Fabric consumption for a knitted top can be calculated by using the following formula:

Consumption in grams = {(L*C) + (B*SL)} *2*GSM/10000 grams (when length units are in centimeter).

Where:

Table 3: Equation legend.

C	=	Chest +allowance
L	=	ength of the body measure + allowance
SL	=	Sleeve length +Allowance
B	=	Biceps +allowance
GSM	=	fabric weight in grams per square meter

Source: Authors, (2020).

Fabric consumption (gm)= {(L*C) + (B*SL)} *2*GSM/10000 gm
= [{(33*25) + (10*2*27.5)} *2*(2.54*2.54) *200]/10000 grams
(Note: 2.54 is inch to cm conversion factor)
= [{825+550} *400*6.45]/10000 grams
= 354.83 grams
For 10000 pieces Required Fabric,
R_F = 345.83*10000= 3458300 grams
= 3458.3 Kgs ≈3459 Kgs

Table 4: Production Capacity.

Required Fabric (Kg)	3459
Knitting Capacity (Kg/Day)	600
Dyeing Capacity (Kg/Day	700
Printing Capacity	2000
Cutting Capacity	700
Sewing Capacity	2000
Finishing Capacity	2000

Source: Authors, (2020).

Table 5: Process Pricing.

Item	**Cost**
Knitting Price Per Kg	$ 3.40
Dyeing Price Per Kg	$ 1.50
Cutting Price Per Kg	$ 0.15
Printing Price Per Piece	$ 0.20
Sewing Price piece	$ 0.30
Ironing & Finishing Price Per Piece	$ 0.20
Labor Cost Per Hour	$ 0.50

Source: Authors, (2020).

Table 6: Product Measurements.

Measurements without allowances (cm)	**Measurement with allowances (cm)**
Chest (C) = 23.25”	+1.75” = 25”
Body Length (L) = 30.5”	+2.50” = 33”
Sleeve Length (SL) = 26”	+1.50” = 27.5”
Bicep (B) = 9.2”	+0.80” = 10”
Fabric GSM =200	

Source: Authors, (2020).

Table 7: Initial decision variables.

Decision Variable	T1	T2	T3	T4	T5	T6
Initial	0	0	0	0	0	0

Source: Authors, (2020).

Table 8: Required constraints.

Constraint	**Output Amount**		**Required Amount**
knitting	0	≥	3459
dyeing	0	≥	3459
cutting	0	≥	3459
printing	0	≥	10000
sewing	0	≥	10000
finishing	0	≥	10000
Total Time	0	≥	60

Source: Authors, (2020).

IV. RESULTS

Table 9: Results of variables.

Decision Variable	T1	T2	T3	T4	T5	T6
Initial	5.765	4.94143	4.94143	5	5	5

Source: Authors, (2020).

Table 10: Result of the necessary restrictions.

Constraint	**Output Amount**		**Required Amount**
knitting	3459	≥	3459
dyeing	3459	≥	3459
cutting	3459	≥	3459
printing	10000	≥	10000
sewing	10000	≥	10000
finishing	10000	≥	10000
Total Time	30.6478571	≥	60

Source: Authors, (2020).

Table 11: Final solution.

Labor cost	$ 367.77
Profit	$ 5,164.28
Product Making Cost	$ 24,467.95

Source: Authors, (2020).

We have used Microsoft excel solver to solve the problem. We can see that the maximum profit is found to be $5164 (Omitting Fraction) and this maximum profit will be gained if the project is completed within 31 days (By rounding up).

V. CONCLUSION

Production planning plays a vital role in setting up the pricing policy of the company. The linear programming model is solved using excel. The results show that lead time can be reduced to 31 days from 60 days to maximize the profit. This method can undoubtedly increase the effectiveness of a manager's decisions ensuring the maximum utilization of current resources. It gives management the ability to choose the best production plan out of many alternatives available. This model can be helpful to reduce the scheduling problems in a composite textile mill.

Production planning techniques have much wider applications than have been discussed in this article. The production models can be solved with different textile mill structures. One possible improvement to the model can be the inclusion of manpower capacities and it can be solved by formulating mixed linear-integer programming models.

Much wider application of the model would be that for a very large size mill which has spinning and knitting plants at different locations. The problem then becomes that of determining yarn and fabric quantities to be produced at the various centers and

the specification of a distribution plan and the optimized transportation routes from the spinning to the knitting centers.

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RESEARCH ARTICLE OPEN ACCESS

DEVELOPMENT OF A LOW-COST MEASURING SYSTEM FOR THE MONITORING OF ENVIRONMENTAL PARAMETERS THAT AFFECT AIR QUALITY FOR HUMAN HEALTH

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ABSTRACT

In many situations or applications, it is essential to evaluate the air quality in relation to human health. For that reason, a monitoring system has been designed with the objective of accurately measuring temporal trends in the air mixture that we breathe. Parameters such as temperature, relative humidity, several inorganic gases (CO_2, O_3, SO_2, CO), the total volatile organic compounds (TVOC) and the concentration of particulate matter need to be measured simultaneously in order to achieve an operational sensing node. With current technology, it is possible to use open-source hardware and software to create a low-cost monitoring system. At present, the development and selection of the hardware, software platforms and the sensors associated with these applications, constitute a scientific and technological interest. The possibility of creating compact, economically accessible systems, based on open-source hardware and software, increases the possibility to perform such analyses at a larger scale and by simple citizens. The proposed system is a prototype in the initial phase, so only the operational capabilities of the system were evaluated during periods of time of 24 and 72 hours of continuous operation, the response of the sensors to step-type inputs and the measurement of background concentrations in urban interior environments.

Keywords: Sensors, Monitoring, Open-Source, Hardware, Software.

I. INTRODUCTION

Several species in air, as well as products derived from them by chemical reactions are responsible for mild problems such as irritation, inflammation and allergic reactions while in other situation the effect on the human body is much worse such as inflammation of the respiratory tract, as well as cancer [1].

Hence, knowing the quality of the air that is breathed is a topic that is investigated by various institutions and organizations at global, national and even local level [2]. Examples of leading organizations dealing with human health related air quality are the World Health Organization (WHO), the Environmental Protection Agency (EPA) or Cuba's Ministry of Science, Technology and Environment (CITMA). Important markers that give an insight in air quality can be classified in 3 categories: (1) inorganic gases such as sulfur dioxide (SO_2), carbon monoxide (CO), ozone (O_3) or nitrogen dioxide (NO_2), (2) organic gases such as the total volatile organic compounds (TVOC), or specific products such as benzene, and (3) particulate matter (PM) such as all particles smaller than 2.5 µm ($PM_{2.5}$) or all particles smaller than 10 µm (PM_{10}).

A large number of air quality standards developed by the aforementioned institutions estimate the air quality by combining information of inorganic pollutant gases (SO_2, CO, O_3, NO_2) and particulate matter ($PM_{2.5}$ and/or PM_{10}) [2]. The standards consider the concentration of the pollutants, the time that people are exposed to the pollutions (e.g., short-term exposure time or an exposure time of 8-hourper day) and the impact that the pollution has on our health [3]. It should be emphasized that a community can exists of groups of persons with a different sensitivity toward pollution (e.g., people who suffer from asthma, elderly).

Traditionally, air quality monitoring has been studied for two main purposes: compliance with surveillance legislation, scientific research related to the impact of air quality on our environment, economy or society or more recently citizen science projects [4, 5]. For both purposes, measurements provided by fixed air quality monitoring stations distributed across countries are

considered as reference information sources. These installations ensure high quality measurements because they use reference methods that comply with legislation, they are equipped with certified instruments and the instruments are maintained by strict routines. The investment and maintenance cost of such facilities is high. So their distribution (https://aqicn.org/map/world/) is not homogeneous in all countries, concentrating mainly in developed ones.

An alternative to such high-cost reference stations is the use of semi-professional stations (e.g., Libelium, Vaisala or AQMesh products) For example, AQMesh, is deployed in several cities to measure a wide range of common contaminants of air in outdoor environments [6]. The Libelium Waspmote Smart Environment [7] is deployed in several European cities and on the African continent [8]. Table 1 summarizes the variables associated with air quality measurements performed by these systems and their ranges for urban air referred by the World Health Organization (the range of several gases does not start at zero because of the natural composition of the atmosphere).

Table 1: Variables measured by two commercial products and the acceptable range according to WHO.

Parameter	AQMesh	Libellium Waspmote Smart Environment	WHO
Temperature	-20 °C - 100 °C	-40 °C - 85 °C	0 °C - 65 °C
Humidity	0% -100%	0% -100%	0% - 100%
CO_2	0 - 5000 ppm	0-5000 ppm	300 - 1000 ppm
CO	0 -1000 ppm	0 - 500 ppm	0 - 1.57 ppm
NO_2	0 - 20 ppm	0 - 20 ppm	0 - 0.5 ppm
Ozone	0 - 20 ppm	0-18 ppm	0.005-0.070 ppm
SO_2	0 - 100 ppm	0 – 20 ppm	0 - 2 ppm
Suspended particles	0 - 350 mg / m3	0 - 300 mg / m3	0-7 mg / m3

Source: Authors, (2020).

Besides, mid-price ready-made measuring devices, there is also the option to build its own measuring device by combining individual hardware components (i.e., low-cost sensors and microcontrollers such as Arduino or Raspberry Pi) and writing accompanying software. These alternatives can be used at fixed locations to analyze outdoor or indoor air, and due to its lower cost, it is possible to deploy several measuring nodes in the zone of interest. The compact size of these devices makes it possible to transport them by vehicles or persons while measuring. When the measurements are complemented with GPS-information, then small areas or whole cities can be mapped.

The amount of literature concerning the design and the use-cases of monitoring systems based on open-source hardware and software and low-cost sensors (LCS) is growing fast [9-13]. In such designs, the real time analysis of air quality is usually performed by coupling a multitude of low-cost sensors to a single microcontroller to simultaneously measure the parameters summarized in Table I. Some of the proposed designs are used in citizen science projects. For some of these platforms, information of a large number of "Do It Yourself" measuring devices are sent through internet to a common Cloud platform. (e.g., Luftdaten-platform, the U-Sense platform, Purple air) to make the information available to the rest of the user community. However, for such applications information about the calibration of sensors is often limited. This makes the information collected up to a certain level unreliable, as several authors debate [14-18]. The other side of the spectrum are research groups that evaluate the performance of such measuring devices by comparing them with reference devices. The comparison can be done by placing low-cost and reference device in a closed box where the environmental conditions can be changed in a controlled way. Another method is to place the low-cost devices in the vicinity of the air quality monitoring stations to study the differences in measurements. In-field calibration in an uncontrolled environment can be done by machine learning where the measurements of the monitoring stations are used to label the measurements of the low-cost devices [19-22]. However, such high-end calibrations are not always accessible to researchers. In addition, the high-end calibrations are not in accordance with the low cost of the self-assembled measuring device. The research presented in this contribution seeks to delve into the strategy for the development of sensor nodes with low-cost open source hardware and software using sensors available on the market. The goal is to obtain a simple hardware design and a set of low-cost procedures to calibrate the sensors so that a reliable monitoring system can be obtained that is capable of providing accurate information for decision-making. Here we propose 2 simple methods as a first reliability test of the prototype: (1) generating sudden changes in ambient air under controlled conditions and check if the prototype respond to them, and (2) performing a small in-field measuring campaign (72 hours) and check if some typical events such as day-night cycles or moments with elevated amounts of traffic result in abrupt changes in the trends.

II. MATERIALS AND METHODS

In today's market, a variety of ready-made air quality measuring devices are for sale and many manufacturers offer these platforms with product information, use cases and technical support for application development. Also, large communities of developers provide hardware designs and software for free. These circumstances make it possible to rapidly develop a prototype. A wide range of sensors covering the spectrum of gases and particulate matter required for an air quality application can be found on the market [6]. They are based on various detection methods based on electrochemistry, photo ionization or light scattering. The available sensors have variety of accuracies, dimensions and power requirements. For the designed application, size and energy requirements are important because operation on batteries and portability are key requirements for future applications. System components were selected to satisfy these criteria, also following an economic criterion of having an operating prototype at a relative cost of 300.00 USD and able to operate autonomously for at least 24 hours.

III. DESCRIPTION OF THE HARDWARE

From the commercially available computing platforms, the Arduino MEGA 2560 was selected because it meets all the anticipated needs and has the most reasonable price of those analyzed. Clone versions of the Arduino MEGA 2560 provide a hardware and software development environment for a price of around 15 USD. It has 54 I/O digital pins and 16 input pins associated to 10-bit analog converters. It provides pulse width modulation (PWM) outputs and incorporates digital serial communication interfaces such as I2C, UART and SPI. Among the potential for application development is having code libraries that allow adding hardware modules to equip the system with new capabilities, including: wireless communications, wired TCP / IP or external storage. The benefits of the Arduino MEGA 2560 for the development of the prototype are enhanced with the inclusion of the Arduino Mega Click shield from the manufacturer Mikroe

(https://www.mikroe.com/arduino-mega-click-shield). This shield carries the signals from the MEGA 2560 pins to 3 mikroBUS ™ type sockets that allow the assembly of 3 additional hardware modules from the same manufacturer without wiring or soldering (iAQ-Core, rtc-click, microsd-click). Above Mikroe's shield is a second custom-designed shield, where the remaining sensors and their conditioning were included. This shield is wired to the Mikroe shield to obtain the analog and communication signals necessary for its operation.

The selected sensors should be available on the Internet for online purchase at a reasonable cost, have several favorable reports on their use, and should be implemented in already published designs [5, 12]. Table 2 shows: manufacturer, purpose, measurement ranges and energy requirements of the selected sensors. In addition to the sensors, a storage system (microsd-click) and real time clock (rtc-click) of Mikroe were also added.

Table 2: Components embedded into the proposed system.

Sensor	Parameter	Interface	characteristics	Energy consumption
Aosong Electronics "AM2302" (DHT22)	Humidity	Digital simplified "1-wire"	0% -100%	500 uA
	Temperature		-40 ° C to 80 ° C	
Mikroe 2529 "iAQ-Core"	Air quality CO_2 + TVOC	I2C	CO_2: 450 - 2000 ppm TVOC: 125 – 600 ppb	<0.2 mA
Zhengzhou Winsen "MQ-131"	Ozone low concentration	analog	50 ppb to 2 ppm	45 mA
Sharp "GP2Y1010AU0F"	Suspended particles	analog	0.65 V / (mg / m3)	<2 mA
SGX Sensortech "EC4-20-SO2"	Sulfur dioxide	analog	0-20 ppm	<5 mA
Mikroe 924 "microsd-click"	Storage	SPI	16 GB	25 mA
Mikroe 947 "rtc-click"	Real Time Clock (RTC)	I2C	0.1 s	25µA
TOTAL				≈ 75mA

Source: Authors, (2020).

A cost analysis based on the market value of integrated components in the system developed and discarding engineering design and assembly costs is shown in Table 3, the same verifies that the economical criterion established was satisfied.

Table 3: Cost of components embedded on the system.

Components	Price (USD)
Arduino Mega 2560 (clone)	17.00
Arduino Mega Shield	9.90
AM2302 (DHT22)	22.00
"IAQ-Core"	79.00
MQ-131	29.99
"GP2Y1010AU0F"	5.00
EC4-20-SO2	80.00
uSD	16.00
RTC	21.00
Battery	30.00
Box	17.00
Total	326.89

Source: Authors, (2020).

Figure 1 shows the interconnection of the different hardware elements through the Arduino Mega Click shield board. The board established a simplified serial communication by connecting 3 mikroBUS connectors, 3 analog inputs (A6, A10 and A15) with a digital pin (12). RC filters are used to suppress noise levels during measurement of analog signals. The interconnection with the developed Monitoring Software on a PC is established through the USB port of the Arduino MEGA 2560.

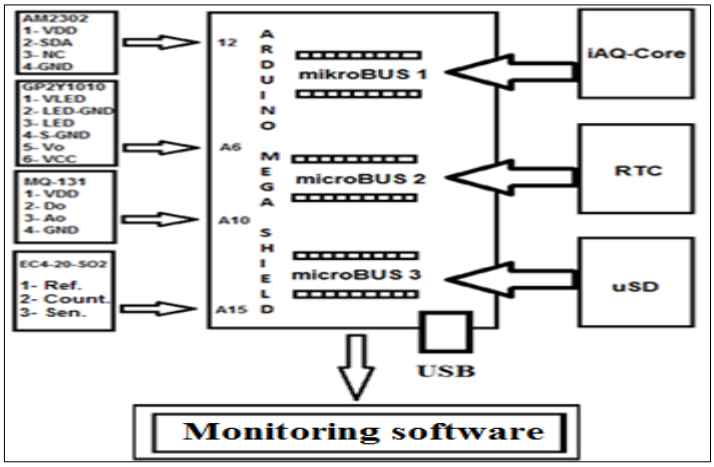

Figure 1: Interconnection of sensors, computing unit and Monitoring Software.
Source: Authors, (2020).

IV. DESCRIPTION OF THE SOFTWARE

After defining the hardware design, the operational logic of the implemented software is described. It was developed in the Integrated Development Environment (IDE) version 1.8.5 provided by Arduino. The programming language used is C/C++. Programming is based on a set of open libraries provided by the collaborative development platform GitHub, both for handling the sensors and for the communication between them, the Arduino board, the RTC and the storage. The software developed initializes the hardware, variables concerning the analog and digital pins are defined, followed by a check if the sensors are present by a simple reading of each assigned channel. Taking the ozone sensor MQ-131 as an example, the process would flow as shown in Figure 2. After verifying the presence of sensor MQ-131, the preheat time is set to obtain valid measurements, at that point a cycle is started in which the sensor reading is performed, filtered and validated. Validation is based on the detection of maximums and minimums, also minimum and maximum thresholds based on last values.

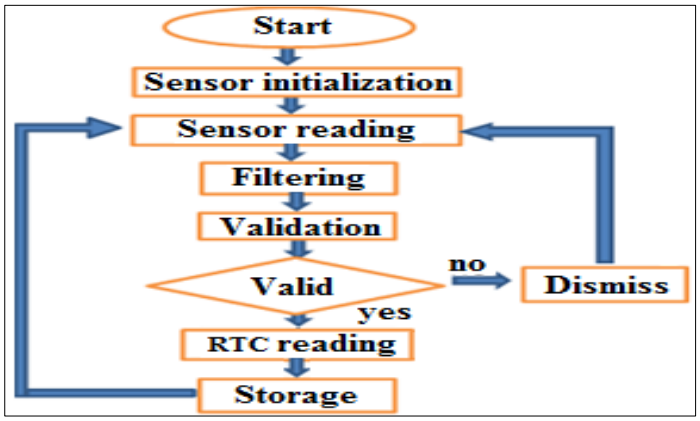

Figure 2: Flowchart of a measuring cycle.
Source: Authors, (2020).

The Monitoring Software, the prototype's graphical user interface (Figure 3), was developed in the Qt Designer environment, to be cross-platform. Qt is currently one of the most commonly used software for the creation of graphical user interfaces in Internet of Things applications and data acquisition systems [23, 24]. The Monitoring Software allows the visualization of information on a PC or other computing device that is sent by the prototype via USB. In the Monitoring Software, each sensor is associated to a different tab page. Each page contains the configuration of parameters (sampling frequency, alarm levels...) and also a graph capability to analyze the individual behavior of the measurement. The acquired data can be graphed from the stored material or in real time after its validation. The configurable sampling rate of the sensors allows to adjust the prototype to the dynamics of the environment to be studied. Valid measurements are stored in a text file (CSV-file) with database structure in the micro SD memory of the prototype. The text file starts each entry of readings with the date provided by the real time clock. If the prototype is connected to a PC or other computing device via USB, it will also send each entry of readings to the Monitoring Software. Each time the prototype is powered, it assumes as operating parameters (sampling frequency of sensors, alarm levels...) the latest configurations saved in it, without the need to be connect to any external computing device.

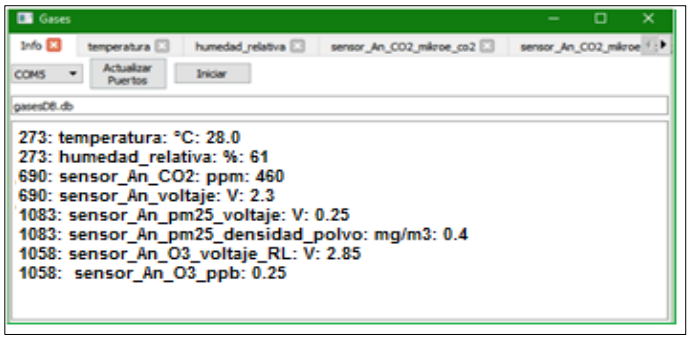

Figure 3: Monitoring Software interface.
Source: Authors, (2020).

V. RESULTS

As a first result of the investigation, the low-cost system prototype shown in Figure 4 satisfies the requirements imposed in terms of total cost and portability, having dimensions of only 101 mm x 53 mm x 70 mm and a weight of less than 300g. Given its low consumption, , , a cell phone charger that provides 5V / 500mA was used as a power source. In addition, a module comprising a solar panel and a Lipo battery with a capacity of 20,000 mAh (Amazon: Solar Charger Power Bank 20000mAh) was included for autonomy in terms of energy. The same in the evaluations at 72 hours with the prototype connected, demonstrated not to fall below 50% of its capacity.

Figure 4: Photo of the prototype (The sensors can be seen on top of the shield. The Arduino can be seen below that shield.).
Source: Authors, (2020).

Sudden changes are generated in the ambient air in the vicinity of the prototype shown in Figure 4. In Figure 5 and 6 the response of the temperature and humidity under the influence of a hand hair dryer is evaluated. Jumps can be seen from the environmental conditions of 22 ºC and 72% RH, after applying the hot air flow. Heating up air results in a sudden increase in temperature and a drop in relative humidity. The sensor responds in a matter of seconds. The abrupt drop of relative humidity occurs first, while the sudden increase in temperature follows a few seconds later.

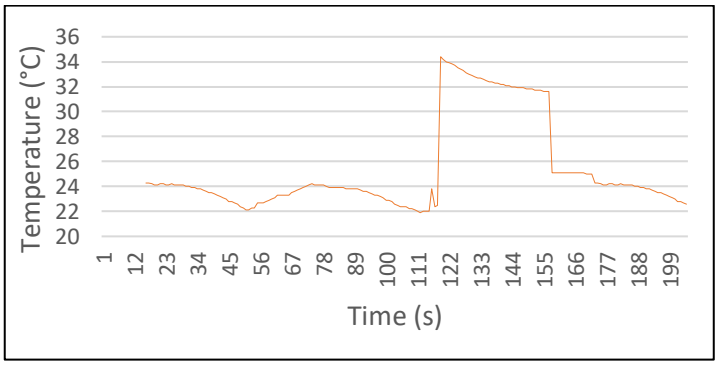

Figure 5: Response of the measuring system to a sudden increase in temperature.
Source: Authors, (2020).

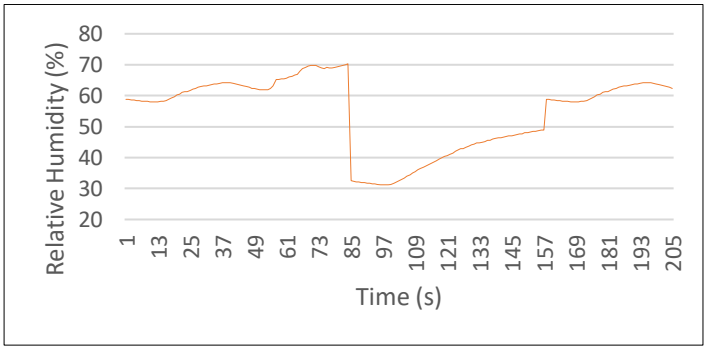

Figure 6: Response of the measuring system to a sudden change in relative humidity.
Source: Authors, (2020).

Figure 7, shows the effect of a sudden change in concentration of particulate matter (PM). In this case, some cigarette smoke was simply blown at short distance towards the prototype. The prototype responded immediately which is seen as a vertical jump in the trend. However, the sensor was not able to measure the concentration. A simple puff resulted in saturation of the sensor.

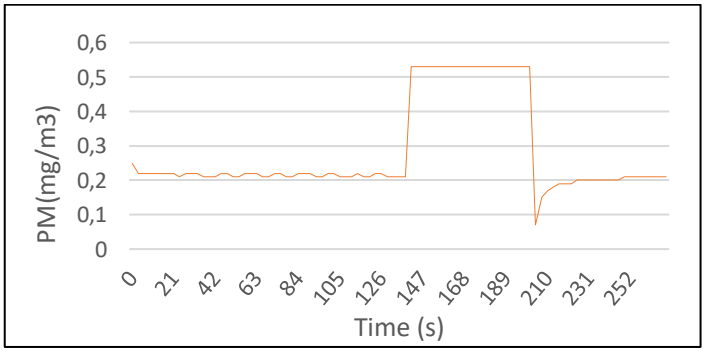

Figure 7: Detection of suspended particles.
Source: Authors, (2020).

In the case of ozone (Figure 8), a sudden increase is generated by fuel combustion. The ozone concentration increases suddenly but keeps on increasing as combustion is running. Fuel ending marks an abrupt end to the signal.

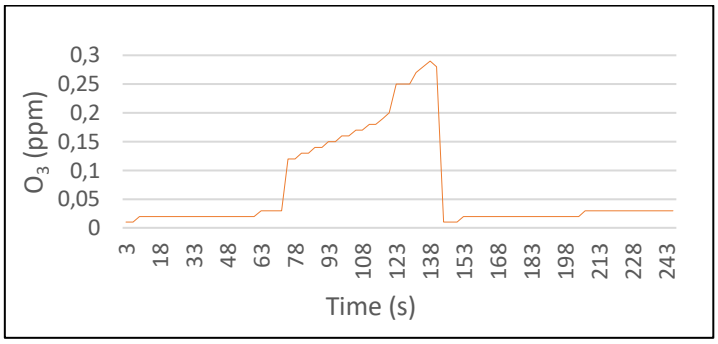

Figure 8: Sensing ozone levels.
Source: Authors, (2020).

Finally, by using the exhaust gases of a "2-stroke" engine, the measurement of the sensors associated with the variables CO_2 and total volatile organic compounds (TVOC) was verified (Figures 9 and 10). For CO_2, the value of 450 ppm is the background concentration of ambient air and was established as the zero of the measurement according to the manufacturer's information. Both signals resulted in a similar pattern. The signal consists of broader peak with a width of about 10 s with superposed spike-like signals. The first 100 s clearly show that the sensors are responding to the engine, suggesting that the sensors are generating a signal and not noise.

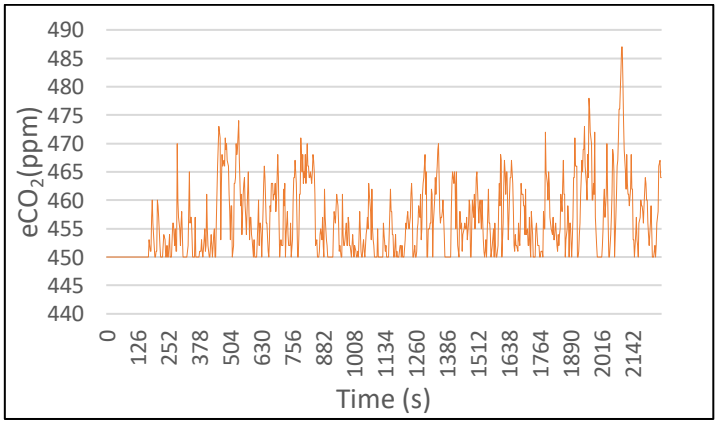

Figure 9: Detection of a volatile compound (CO_2).
Source: Authors, (2020).

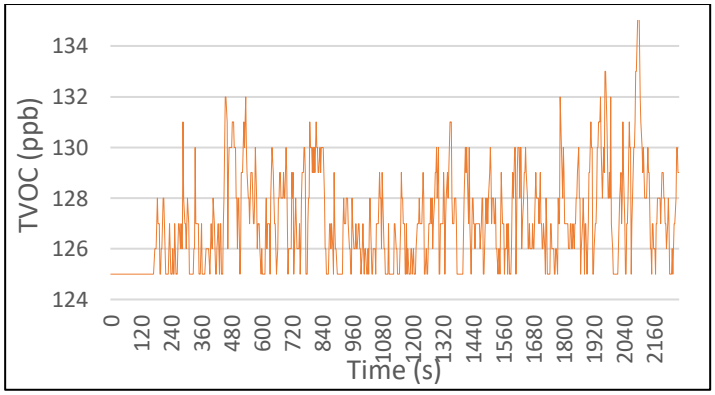

Figure 10: Trend of the total volatile organic compound (TVOC) over time.
Source: Authors, (2020).

The system prototype has been tested in the urban environment of the city of Santa Clara for continuous periods of 24 and 72 hours (battery powered), showing a stable performance in indoor environments close to areas of high vehicular traffic. In Figure 11, the measurement of particulate matter acquired over a weekend (Friday to Monday), in a house near a major road entrance to the city is presented. The system started its measurements at 22:00 on Thursday (0.0) and worked until Monday at 00:00. A repetitive pattern of 12 hours is identified, marked by the increase in traffic from 6:00 to 8:00 and later from 18:00 to 19:00.

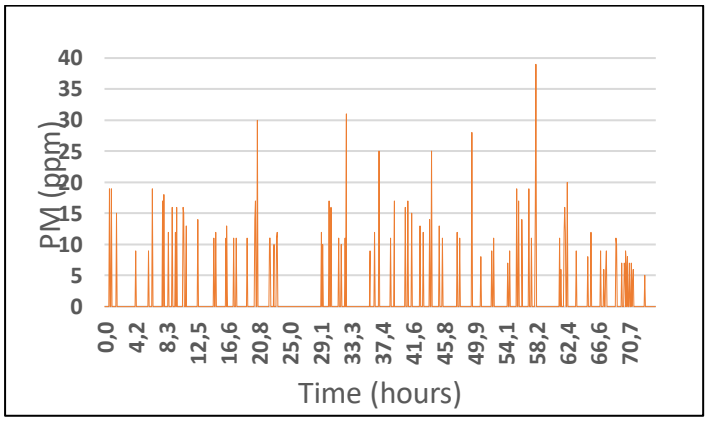

Figure 11: Measurement of particulate matter for 72 hours.
Source: Authors, (2020).

VI. CONCLUSIONS

The developed prototype satisfies the established criteria in terms of variables to be analyzed, size, weight, price and energy requirements, given the expected use time in mobile applications (24h) and the sampling frequency. The proposed architecture, based on free hardware and software, based on low-cost elements, is suitable for use in air quality measurement applications.

This investigation used 2 different methods to check the reliability of the measuring system. The first method relied on the generation of sudden changes in the environmental conditions around the prototype using simple methods. Sudden changes in T and RH were generated by means of a hot air blower. A sudden increase in PM was generated by blowing cigarette smoke towards the prototype. Ozone concentration was altered by fuel combustion. Finally, fuel burning by an engine resulted in sudden jumps in CO_2 and TVOC. Reliability was also checked by a small measuring campaign and controlling if classic events such as day-night cycles, moments of elevated traffic generated sudden changes in the signal.

In future work, low-cost calibration methods will be developed to improve the accuracy of the sensors incorporated in the prototype Likewise, and taking advantage of the extensive features of the selected hardware platform, it is proposed to integrate a larger number of sensors and an LCD interface so that data can be visualized in the field without the need of a connected PC.

VII. ACKNOWLEDGMENTS

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RESEARCH ARTICLE OPEN ACCESS

EFFECTS OF ELECTROMAGNETIC INTERFERENCE CAUSED BY LIGHTING TECHNOLOGIES IN BB-PLC SYSTEMS

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ABSTRACT

Powerline communication (PLC) is a promising technology that allows data transmission through electric power distribution networks, with the advantage of using an existing infrastructure, reducing costs in maintenance and installation of telecommunication systems. However, once power systems are not designed specifically for data transmission, it may exhibit limiting electromagnetic interference characteristics for desirable system performance. This paper aims to analyze data rate performance of a Broadband PLC system when operating under conditions of conducted and radiated electromagnetic interference caused by lighting devices. The analyzed data transmission system presented good performance when subject to radiated electromagnetic interference, but was shown to be sensitive to conducted disturbances caused by lighting devices.

Keywords: Powerline Communication, Electromagnetic Interference, Data Rate, LED Lamps, Compact Fluorescent Lamps.

I. INTRODUCTION

The use of telecommunication systems has been growing rapidly in recent decades [1] and, responsively, new technologies and applications arise in the market aiming to meet demands of the sector's evolution.

The telecommunication systems became an important element in power distribution systems operation using Smart Grids. This type of network is a distribution architecture that allows bi-directional communication, together with the energy flow, among system stakeholders (end user and network, for example) [2]. Such network architecture has been gaining space in the electric sector in recent years, mainly with the technological advances coming from the telecommunication systems.

One of the telecommunications technologies applicable to the systems automation and communication is the data transmission through electric power supply networks, the Powerline Communication (PLC) technology, that brings as main advantage the reduction of operational and installation costs of new telecommunications networks, since an existing infrastructure is used as a means of data transmission. Such advantage provided by the PLC technology becomes a factor of relevance in a project when considering the installation of access networks to telecommunications systems, sector which is responsible for around 50% of all infrastructure investment in the area [1].

PLC technology may be classified into two main categories: Broadband PLC (BB-PLC) and Narrowband PLC (NB-PLC) [2]. The BB-PLC category was initially designed aiming household applications [3], however, documents such as the IEEE 1901-2010 standard [4] and the ITU-T G.9960-2010 recommendation [5] have regulated its use also for applications in public power grids, given its promising characteristics for smart meters and advanced networks control applications, as addressed by [6].

Despite having attractive advantages from the economic and technological point of view, PLC systems may present degradation of their operation for such types of applications, due to electromagnetic interference between devices connected to the power grid [7].

Considering the PLC technology, its operational characteristics and the interest in its applicability to telecommunication systems together with electric power grids, in this article is performed an assessment of the performance of a data transmission system using BB-PLC devices. For this, it is

considered situations where the BB-PLC system is subject to adverse conditions of electromagnetic interference in a conducted and radiated form, to which it would be exposed under normal conditions of use.

The followings chapters of this article present a brief approach about some existing regulations for BB-PLC systems, in section II, followed by an introduction about the Orthogonal Frequency Division Multiplexing (OFDM) modulation technique, in section III, the tests methodology and description, in section IV, the results and discussions about this study, in section V and, finally, the conclusions are presented in section VI.

II. BB-PLC REGULATION

In order to standardize the technology, researchers and institutions worldwide have been working together in the development of rules and standards that technology must respect, according to the different regions of use, where disturbance limits are established to ensure the electromagnetic compatibility of such devices.

The IEEE 1901-2010 International Standard addresses on broadband devices operating in power networks with a transmission frequency below 100 MHz, focusing on the balanced and efficient use of the communication channel of the power network by all broadband devices classes that use this channel [4].

The ITU-T G.9960-2010 Recommendation specifies system architecture and functionality for all physical layer components of home network transceivers designed for data transmission, including transmission over power grids [5].

In Europe, the EN 55022 Standard applies to the regulation of information technology equipment by specifying limits for spurious signals generated in the frequency range of 9 kHz to 400 GHz for class A and B equipment [8], applying therefore to the certification of electromagnetic compatibility in PLCs.

In United States (US), the FCC part 15 Regulation contains technical specifications for several telecommunications equipment, including devices designed to be used in connection with public power grids [9], such as PLCs.

In Brazil, in order to regulate the technology of data transmission through power grids, the National Telecommunications Agency (ANEEL) published in 2009, the Normative Resolution nº 527, which approves the regulation on use conditions of radio frequencies for broadband systems through electric power grids. [10].

The Normative Resolution nº 527establishes the technical characteristics necessary for the proper functioning of the broadband device in its specified frequency range, and determines limits of radiation caused by broadband communication systems through electric power grids (BPL) operating at low and medium voltage, as well as exclusion bands, in which such devices may not cause unwanted radiation, since they are frequency bands allocated to the Aeronautical Mobile and Amateur Mobile Service.

The ANEEL also provides requirements and test procedures applicable to the BPL equipment certification in Brazil, classified as Category II [11].

The PLCs devices used in this work present a compliance declaration with the specifications for a Class B digital device, according to FCC Part 15, the US regulation cited.

III. OFDM MODULATION

The performance of the data transmission system through power grids is significantly affected by phenomena such as noise, signal attenuation and multipath propagation, characteristics common to power network channels, since they are not specifically designed for data transmission purposes [12], [13].

In some channels of power distribution network, the number of grid interconnections between transmitter and receiver and their load and branch characteristics cause transmission and reflection of signals among transmission line segments. These phenomena lead to the degradation of propagated information [12]. To mitigate the degradations of the transmitted signal, several techniques are employed; one of them is the type of modulation applied to the signal.

The modulation technique widely used in the PLC technology is the OFDM. In this signal modulation method, a high-speed data stream is divided into a parallel low rate data stream, where these information sets are modulated in QPSK (Quadrature Phase Shift Keying) or QAM (Quadrature Amplitude Modulation) using different orthogonal subcarriers in a frequency range [12]. The modulation technique coding, then provides bits in redundancy, in such a way as multiple signals are sent at different frequencies, allowing the receiver to retrieve bits lost due to impulsive noise [14].

The OFDM modulation enables persistent narrow band interference to be easily manipulated by disconnecting their respective subcarriers [15]. In this way, the OFDM modulation technique is able to handle the phenomena of multipath propagation more effectively than single-subcarrier methods.

IV. METHODOLOGY AND DESCRIPTION OF TESTS

The tests to evaluate the performance of the BB-PLC system, when it is subject to electromagnetic interference caused by lighting devices, were performed at the Technical Lighting Laboratory of the Federal University Fluminense (LABLUX-UFF), which is active in the lighting product certification area.

All measurements were performed in a shielded room with attenuation of radio frequencies up to 30 MHz and dimensions of 3.4 m x 5.3 m.

The BB-PLC devices used are specified with OFDM modulation technique and applied for low voltage usage. As interference sources for the tests, lighting devices were used, since such equipments work with power converters operating in frequency bands that may overlap the BB-PLC operating band.

For measuring the frequency spectrum of the lamps used as interference source and the BB-PLC system, the following equipments were used:

- Line Impedance Stabilization Network (LISN) – 9kHz-30MHz - CISPR 16 specification [16];
- Spectrum Analyzer;
- 13 bands Pre-Selector;
- 2.5 mm² copper power cables.

In the interference tests and measurements of data transmission capacity, two PLCs with the same specifications and manufacturer were used, each one connected to a notebook with GNU/Linux operational system, one operating as a client and one as a server. The LISN network was used to power the PLCs, in order to provide controlled impedance and decouple the test circuit from the supply mains.

For measurements of the maximum transmission rate achievable by the system, under the analyzed conditions, it was used the software tool iperf3, which allows the injection of data packets for the performance evaluation of data transmission networks.

Measurements of electric and magnetic field strength of samples used as sources of radiated electromagnetic interference were also performed, such as their influence on the system data transmission capacity. For these measurements, it was used a broadband non-ionizing radiation (NIR) meter, designed for measurements in the frequency range of 3 kHz to 60 GHz.

As non-controlled electromagnetic interference source, four Compact Fluorescent Lamps (CFL) and three LED Lamps with different power and operating voltage were used, as shown in Table 1.

Table 1: Lamps used as Electromagnetic Interference Source.

Source Code	Technology	Power (W)	Voltage (V)
AM01	LED	20	Bivolt
AM02	LED	9	Bivolt
AM03	LED	6.5	Bivolt
AM04	CFL	45	127
AM05	CFL	45	220
AM06	CFL	20	127
AM07	CFL	20	220
6 Samples Set	LED and CFL	155.5	127
6 Samples Set	LED and CFL	155.5	220

Source: Authors, (2020).

Of these selected interference sources, two are LED lamps complying with the Brazilian electromagnetic compatibility specifications, according to CISPR 15 [17], one is a noisy spectrum LED lamp that exceeds the limits of electromagnetic disturbances acceptable by Brazilian regulations and the last four are noisy spectrum CFLs. The noisy spectrum samples were selected in order to know the performance of the BB-PLC system under such adverse interference conditions.

The electromagnetic compatibility tests for CFLs are not mandatory in the Brazilian market, however, for this study, measurements were performed on the CFLs samples used as interference sources and compared to the limits of the CISPR 15 standard. As result of such tests, the CFLs presented a noisy characteristic spectrum, thus not meeting the standard specifications.

The less noisy lamps, in accordance with CISPR 15 standard, are the samples coded as AM02 and AM03. The LED lamp coded as AM01 and all used CFLs, are samples with noisy characteristic spectrum in the frequency range of 9 kHz to 30 MHz, thus not complying with the limits established by such standard.

The last two interference sources presented in Table 1 as "Set of 6 Samples", comprise two groups of 6 lamps, containing CFLs and LEDs, the first group operating at the voltage of 127V and the second group at the voltage of 220 V. Such interference sources were inserted in parallel in the PLCs power circuit to analyze the effects of the electromagnetic interference caused by the set on the system data transmission.

As mentioned before, LED lamps and CFLs, have typical operation frequency range overlapping the PLCs band. Since they emit conducted electromagnetic interference in the band of 9 kHz to 30 MHz (band with specified interference limits [17], and the used PLCs operate at the frequency range of 2 MHz to 30 MHz.

Figure 1 shows the frequency spectrum of the BB-PLC system used and the Quasi-Peak (QP) and Average (AV) limits specified by the CISPR 15 standard [17] for lighting devices, to which only AM02 and AM03 interference sources comply. The peak values of three samples frequency spectrum are also presented in Figure 1, which are: the sample peak value with the highest noise level among those used (AM01-blue line) and the peak values of the models samples most commonly used in homes, where, one is of LED technology (AM02-purple line) and another is of CFL technology (AM06-green line).

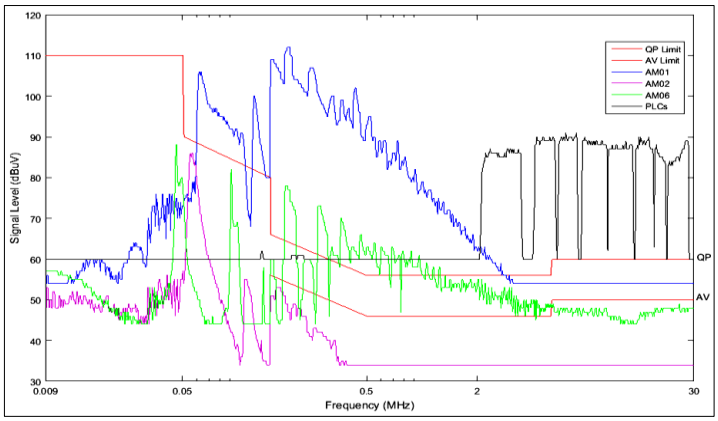

Figure 1: Characteristic frequency spectrum of the lamps used as interference source, PLCs and limits specified by the CISPR 15 standard for conducted electromagnetic disturbances of lighting devices.
Source: Authors, (2020).

The data rate measurements for performance analysis of the BB-PLC system, when subject to electromagnetic interference caused by lighting technologies, were performed considering two different forms of interference, the form conducted by the mains terminals and radiated in order to generate electric and magnetic field, as discussed in the sub-items below.

IV.1 MAINS TERMINALS ELECTROMAGNETIC INTERFERENCE

For measurement of the BB-PLC system performance, when subject to conducted electromagnetic interference, three different scenarios were considered, where the length of power cables between PLCs and interference source and the connection manner were modified. In both measurement scenarios the LISN network powering the used devices and the same samples as sources of electromagnetic interference were used. The connection of the PLCs and interference sources was made in the same circuit, in parallel.

The test settings were designed considering IEC CISPR 16-2-1 standard specifications [18], which determine measurement methods for conducted electromagnetic interference. Therefore, all measurements were performed inside a shielded room, on a table of non-conductive material and 80 cm high. The minimum distance of the equipment under test (PLCs) for the reference ground plane (metallic wall) was 40 cm and for the LISN network was 80 cm, according to [18].

Once the used PLC devices are specified as bivolt and may operate at two voltage levels (127 V and 220 V), the measurements of the system data transmission rate, when influenced by conducted electromagnetic interference, were performed for both system operating voltages.

It was established a data transmission time of 120 seconds between the two PLCs and, for each of the interference sources described in Table 1, 10 measurements of the data rates were performed for subsequent determination of the mean value among them, in order to obtain a better confidence level in results.

Figure 2 shows the schematic with the scenario 1 test setup. In this scenario, it was considered 80 cm for the cable length between the PLCs and the connection point of the interference source. It was also used an 80 cm length cable to energize the

interference source, in order to mitigate possible influences of radiated disturbances in data transmission, since this scenario aims to analyze the influence of conducted interferences. Such configuration of the interference source power cable was also maintained for scenario 2.

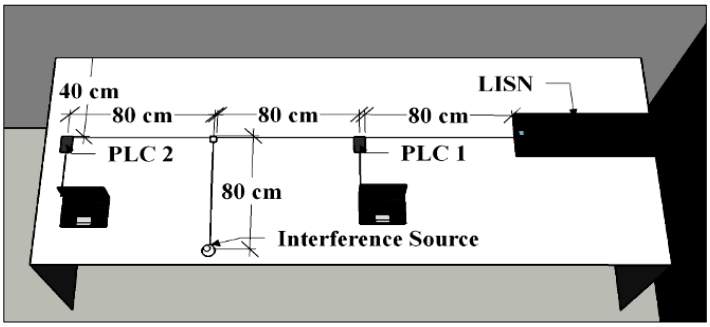

Figure 2: Measurement of the influence of conducted electromagnetic interference on the BB-PLC system performance - Scenario 1.
Source: Authors, (2020).

The second scenario adopted for analysis of the BB-PLC system performance is represented by the scheme of Figure 3. In this scenario, the length of the power cables between the PLCs and the connection point of the interference source was reduced to 40 cm, aiming to know the cable influence on the system data transmission rate.

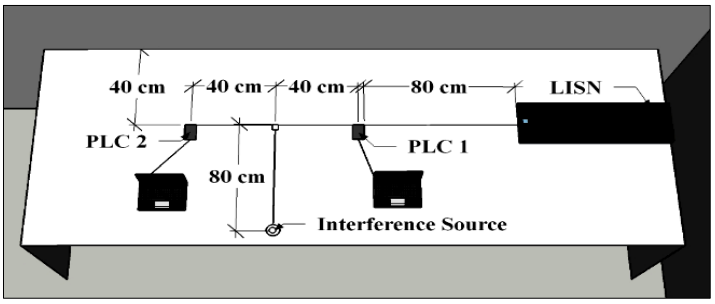

Figure 3: Measurement of the influence of conducted electromagnetic interference on the BB-PLC system performance – Scenario 2.
Source: Authors, (2020).

The scenario 3, represented by the scheme of Figure 4, comprises the measurements performed for the system where the PLCs and the interference source are connected directly to the LISN by 80 cm length cables. The devices were arranged in order to keep a distance of 40 cm from each other.

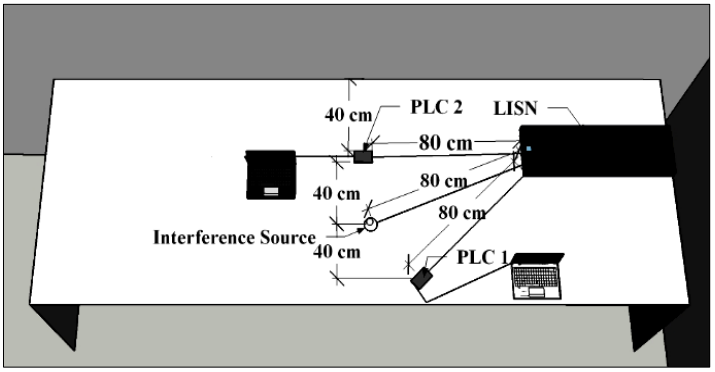

Figure 4: Measurement of the influence of conducted electromagnetic interference on the BB-PLC system performance – Scenario.
Source: Authors, (2020).

IV.2 RADIATED ELECTROMAGNETIC INTERFERENCE

In order to know also the influence of the radiated electromagnetic interference in the data transmission through power grids, using a BB-PLC system, measurements of the data transmission rate when influenced by electric (E) and magnetic (H) field generated by LED lamps and CFLs, were performed. In the tests the PLCs devices were connected in a different circuit from the interference source, in order to eliminate the influence of the electromagnetic interference conducted by the mains terminals. In this way, the PLCs were energized through the LISN, while the interference source was connected to a second supply circuit.

As non-controlled interference source, the lamps coded as AM01, AM02, AM05 and AM07 in Table1I were used.

Initially, measurements of the electric and magnetic field strength generated by the interference sources were performed, using a NIR meter. The measuring equipment was positioned 20 cm distant from the interference source and, the measurement time was established in 6 minutes, considering, for the final analyses, the mean value of the measurements performed in this time interval. The measured values of the field strength generated by the used samples and by the PLCs are presented in Table 2.

Table 2: Electric and Magnetic Field Strenght generated by devices used for Radiated Electromagnetic Interference Tests.

Device	E (V/m)	H (A/m)
PLCs	0.18	0.0075
AM01	0.39	0.0079
AM02	0.2	0.0084
AM05	20.17	0.0086
AM07	6.78	0.0088

Source: Authors, (2020).

It is possible to note that the CFLs (AM05 and AM07) are the ones with higher electric field strength. Based on a study already performed in [19], such behavior was expected for this lighting technology.

For measurements of data transmission rate under the influence of radiated electromagnetic interference, transmission time of 3 minutes was established. The measurements were performed considering two scenarios, where the distance between the interference source and the PLCs was modified. In the first scenario, a distance of 1 m was considered between the interference source and each of the PLCs, as shown in Figure 5; in the second scenario, this distance was reduced to 50 cm, as presented in Figure 6.

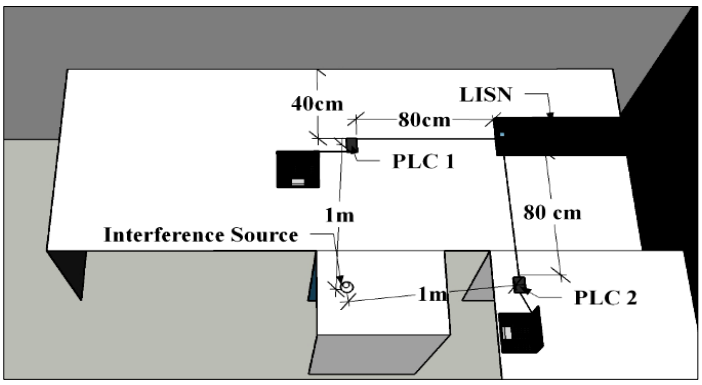

Figure 5: Measurement of the influence of radiated electromagnetic interference on the BB-PLC system performance - Scenario 1.
Source: Authors, (2020).

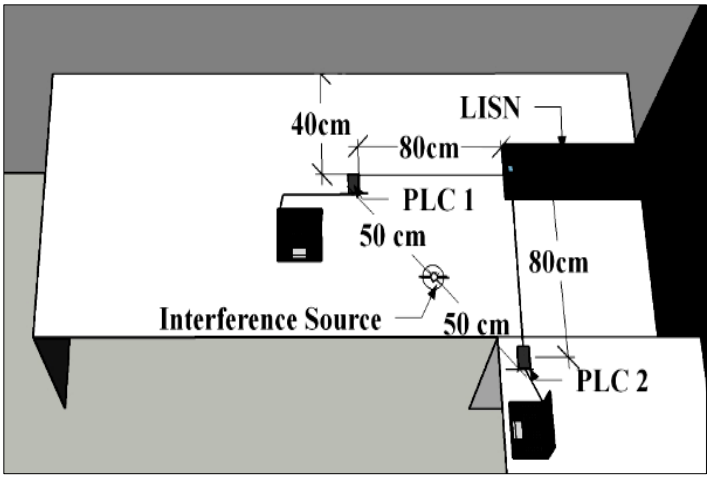

Figure 6: Measurement of the influence of radiated electromagnetic interference on the BB-PLC system performance - Scenario 2.
Source: Authors, (2020).

V. RESULTS AND DISCUSSIONS

In this section, results and discussions are presented, in order to analyze the performance of the BB-PLC system for each of the interference forms and scenarios discussed in this study.

V.1 BB-PLC SYSTEM PERFORMANCE WHEN SUBJECT TO CONDUCTED ELECTROMAGNETIC INTERFERENCE CAUSED BY LIGHTING TECHNOLOGIES

Figures 7 and 8 present the results obtained for measurements of data transmission rate, when the BB-PLC system is subject to mains terminal electromagnetic interference caused by lighting devices

Figure 7 shows the results for the system operating at the voltage of 127 V, with the bivolt samples and those operating only at 127V (AM04 and AM06). Figure 8 shows the results for the system operating at the voltage of 220 V, with the bivolt samples and those operating only at 220 V (AM05 and AM07).

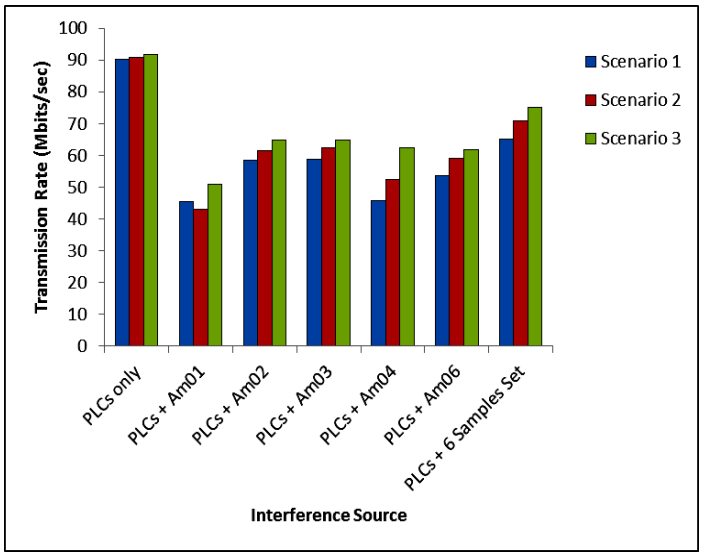

Figure 7: Transmission rate of the BB-PLC system operating at 127 V with insertion of conducted electromagnetic interference.
Source: Authors, (2020).

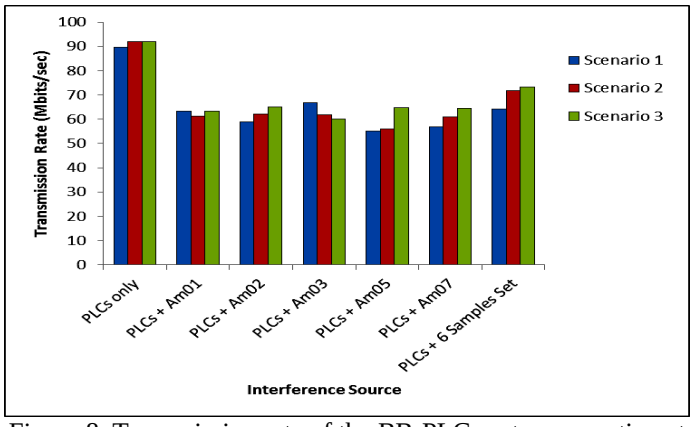

Figure 8: Transmission rate of the BB-PLC system operating at 220 V with insertion of conducted electromagnetic interference.
Source: Authors, (2020).

The columns identified in the figures as "PLCs only" refer to the BB-PLC system transmitting data without insertion of interference source into its power circuit. The other columns sets in the figures refer to the system transmitting data with the individual insertion of each of the interference sources shown in Table 1.

It is possible to observe by analyzing the graphs that the data transmission rate variation among the different scenarios is small for both analyzed voltage levels. The largest results difference among scenarios was found for insertion of the interference source AM04, in the 127 V voltage level, between scenarios 1 and 3, corresponding to 18%, calculated relative to the maximum transmission rate value, measured for the BB-PLC system transmitting data without the insertion of an interference source. The other variations of the transmission rates among the scenarios were lower than 11%, for both voltage levels.

The interference source that most affected the data transmission rate of the BB-PLC system was the AM01 source, for the system operating at 127 V, in the second scenario. Such interference source caused a transmission rate reduction of 53%, due to conducted electromagnetic interference.

V.2 BB-PLC SYSTEM PERFORMANCE WHEN SUBJECT TO RADIATED ELECTROMAGNETIC INTERFERENCE CAUSED BY LIGHTING TECHNOLOGIES

Figure 9 shows the results of the data transmission rate obtained for the BB-PLC system, when operating under influence of radiated electromagnetic interference caused by LED and CFL lamps technologies.

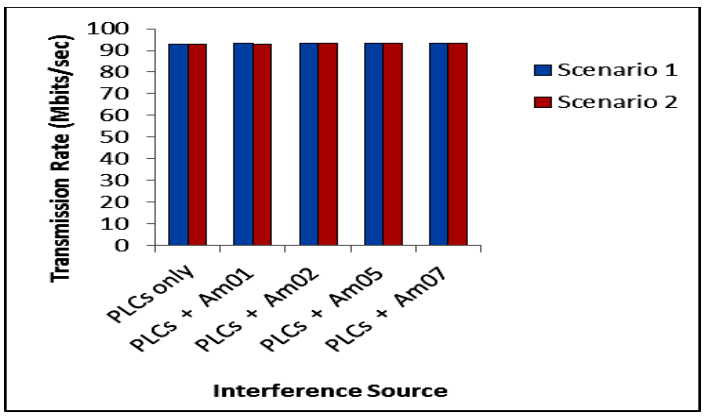

Figure 9: Transmission rate of the BB-PLC system operating with insertion of radiated electromagnetic interference.
Source: Authors, (2020).

It is possible to observe by analyzing the graph presented in Figure 9 that the data transmission rate variation among the analyzed scenarios of radiated electromagnetic interference conditions, when existing, is small, occurring only in two occasions: insertion of the interference source AM01 and the interference source AM05; where, 0.43% and 0.11% are the variation values for each occasion, respectively, calculated relative to the maximum transmission rate value that was measured for the system operating without insertion of interference source.

It is possible to note also that the radiated electromagnetic interference, caused by the used lighting devices, does not interfere significantly in data transmission of the BB-PLC system, which maintained its transmission rate around 90 Mbits/sec, even when approximating the radiated interference sources in scenario 2.

VI. CONCLUSIONS

This work presented a series of tests performed in order to evaluate the BB-PLC system performance, when it is subject to adverse conditions of electromagnetic interference present in the data transmission channels in power distribution networks.

Electromagnetic interference conducted by the mains terminal and radiated electromagnetic interference were considered in this study. As interference sources, CFLs and LED lamps were used, once these devices emit noise in a frequency range that overlaps the transmission band of BB-PLC systems, besides being equipment with possibility of operation in the same circuit and environment of such system.

In the analyzed data transmission system, two PLCs devices of the same manufacturer and specifications were used. Such PLCs use OFDM signal modulation technology and are designed for use in low voltage

The analyzed BB-PLC system presented good performance when subject to radiated electromagnetic interference caused by the used lamps technologies; however, it showed considerable sensitivity to conducted electromagnetic interferences caused by such devices in the mains terminals, since, a reduction of up to 53% in data transmission rate could be found for insertion of this interference form.

By analyzing the different scenarios discussed, it is also possible to conclude that the BB-PLC system suffers small variation with the length of the power cable between the two PLCs devices, and presented a low oscillation in the data transmission rate among the scenarios discussed.

As mentioned in item I of this work, data transmission technology through power grids is promising for both telecommunication and electric power systems, due to its applicability, among others, to smart grids. Therefore, it is pertinent to dedicate attention to topics involving existing limitations for such technology, in order to mitigate obstacles to its advancement.

Limitations of the BB-PLC system involving electromagnetic interference may be moderated by measures to be adopted in the transmission channels, the power grids, through filter application, for example; or by adopting improvements in the PLC technology, which may be done through the implementation of bit allocation algorithms aiming the maximization of data transmission rate, considering transmission channels with noisy characteristic spectrum and low signal-to-noise ratio (SNR).

Algorithms that provide adaptive modulation according to the transmission channel conditions, in order to maximize the reachable margin and/or data rate, have been proposed by several researchers in the last decades [20]–[31], and may represent a promising technique to implement improvements in data transmission technology through power distribution networks.

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RESEARCH ARTICLE OPEN ACCESS

APPLICATION BASED ON FUZZY LOGIC TO EVALUATE IMPLEMENTATION OF TPM IN INDUSTRIES

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ABSTRACT

The aim of this paper is present a study on the development of a fuzzy logic application to evaluate the susceptibility of the Total Productive Maintenance (TPM) methodology in industries which provides a diagnosis of the set of indicators from the inference system. This study is relevant because the TPM in the industries has been shown as a management tool with excellent results, contributing to increase the general capacity of utilization of the plants with direct impact on the availability of equipment and consequently increase of production. This work developed an application that through fuzzy logic, can evaluate the susceptibility of TPM deployment and identify the areas that offer opportunity for improvement and potential for this philosophy. To do so, the definition of system input variables and the criteria for implementation form the basis of this study.

Keywords: Total Productive Maintenance, Industrial Maintenance, Performance Index, Maintenance Management.

I. INTRODUCTION

The result of the various socio-cultural changes throughout the twentieth century has been observed since the 50, the appearance of a set of points of attention for the companies, highlighting among others, the following:

- Improvement of the quality of the products;
- Growing concern for safety and the environment;
- Reduction of delivery times;
- Greater variety of products.

These points represent an opportunity for companies to become more versatile and efficient.

In this way it is possible to say that an increase in efficiency and versatility in companies, which present automation of the production process, is only possible when there is an improvement of the operating conditions of the equipment. This improvement is promoted through maintenance, and an extent review about use of management tool as facilitator of the industrial maintenance plan is presented in [1].

Total Productive Maintenance (TPM) is a methodology created with the aim of increasing production efficiency by implementing efficient equipment maintenance, having a methodical nature of implementation (TPM pillars), which promotes the Involvement of all employees as a way to increase their sustainability and effectiveness.

The implementation of TPM is a process of corporate change and among success stories, there are also cases of failure. The efficiency of the TPM is directly related to the requirement to change

Behavior and attitude of employees within the routine in the company's activities, focus on the result, a suitable basis for corporate change, and there are rare cases that during implantation, activities to achieve change do not provide the results intended. For [2] reports key factors for the success of TPM deployment in companies.

To occur corporate change, such as TPM, the company must have the necessary basis for planning activities, directing to operator maintenance, preventive maintenance, training, and maintenance, among others. If the magnitude and the reasons for the losses are not known, the activities will not be allocated to the solution of the large losses.

Examples of the success of TPM deployment in different industrial sectors are presented in: Manufacturing Company for automotive parts [3], others [4] cite examples of mining installation, in electronic industries there is an example by [3], [5] and present a example in offset companies [6].

As a consequence of the initial diagnosis and understanding of the major barriers in implementation, it is understood that the process becomes more agile and consequently less traumatic the corporation.

II. LITERATURE REVIEW

Production environments have recently changed so quickly that the competitiveness of the manufacturing system has increased. Manufacturing companies have invested a lot to improve their manufacturing performance in terms of cost, quality and flexibility in an effort to compete with other companies in the global market. In industrial companies there are varieties of problems that can affect the cost of manufacturing, product quality and delivery time of products to customers: selection of manufacturing technology, selection of maintenance strategy, machine (process) location, evaluation of quality function, among others [7].

Maintenance, as a system, plays a key role in reducing costs, minimizing the downtime of equipment, improving quality, increasing productivity and providing reliable equipment and as a result achieving goals and organizational objectives [7].

One of the main expense items for manufacturing companies is the maintenance cost that can reach 15-70% of the production. On the other hand, a third of all maintenance costs are the result of unnecessary maintenance activities, so the selection of the maintenance strategy greatly affects manufacturing costs [7].

In literature, maintenance can be classified into two great main types: corrective and preventive.

Corrective Maintenance: It is the maintenance that occurs after the system fails, and it means all actions resulting from failure.

Preventive maintenance: It is the maintenance that is performed before the system failure in order to retain equipment under specified conditions to quote: Periodic inspections, detection and prevention of incipient failures. According to the literature, the strategies are as follows:

(1) Corrective maintenance: This alternative maintenance strategy is also called fire-fighting maintenance, failure.

(2) Time-based preventative maintenance and may refer to the time of the calendar, operating time or age: according to equipment reliability characteristics, maintenance is planned and is performed periodically to reduce the frequent failure and sudden.

(3) Condition-based maintenance: the maintenance decision is made depending on the measured data of a sensor array. When using the condition-based maintenance strategy. Up to date, several monitoring techniques already available, such as vibration monitoring, lubrication analysis and ultrasonic testing.

(4) Predictive maintenance: Predictive maintenance is the maintenance strategy that is capable of predicting trend of performance degradation and machine failures by analysing the data of the observed parameters.

Quantitative criteria can be affected by evaluating alternatives, which can make selection a complex and challenging process. In many cases, the decision-maker has inaccurate information about alternatives in relation to a variable. Proactive maintenance and has received worldwide attention as the most important means of achieving unreachable economies by conventional maintenance techniques. The approach replaces the "Reactive failure" maintenance philosophy by "proactive failure" by avoiding the underlying conditions that lead to machine failures and degradation. Unlike predictive/preventive maintenance, proactive maintenance creates cone-like actions that aim at the root-failure causes, not just symptoms.

Methods may not deal with problems effectively when information is inaccurate. These classical methods, both deterministic and random, tend to be less effective in transmitting the characteristics of inaccuracy.

The diffuse cluster theory that was proposed by [8] is a powerful tool for dealing with inaccurate data. They are usually expressed by linguistic terms and then defined in diffuse numbers.

The complexity of industrial processes and business systems makes the decision on the maintenance strategy and methodology to be implemented complex. Due to this situation, a bit of the design decision-making process is necessary to help managers in reducing decision failures. In this work, the analysis of the implementation susceptibility and the selection of the maintenance strategy were proposed, whose two main characteristics are the use of qualitative and quantitative data and decision-making through a process interactive with maintenance and specialists.

The main characteristics of the proposed approach, in contrast to those of other existing methods, are as follows:

In the proposed approach, several decision makers can express their opinions from their knowledge and experience, about the importance of criteria and evaluation, based on a checklist created from the main items of each column of the TPM [9].

The proposed approach is capable of dealing with qualitative and quantitative data. The inaccurate declarations of decision makers can be analysed by the approach proposed through fuzzy theory. The fuzzy theory can be applied in different areas as: sales demand prevision [10] or industrial process analysis [11].

Decision makers can interact with intermediate solutions to improve mathematical results with their experiences, so that an intermediate solution will be the ultimate ideal solution.

Dedicated to this area [7] report that researchers present a revision of some basic decisions about the theory and discussed their applicability in the selection of maintenance strategies. They also proposed a method to find the criticality to address strategies and simplify the complex maintenance criteria, presented a new approach to optimal maintenance strategy for each class of systems in a just in time environment, In this work are considered 16 characteristic factors that could play a role in the selection of the maintenance strategy, in another work, an approach to decision-making was proposed. They used game theory for a decision when the customer (the maintenance receiver) wants to decide whether to have a service contract or not.

According to [7], they proposed a method to select the most effective maintenance strategy according to different costs of loss of production and maintenance of each maintenance strategy. Another job proposed a cost-based model and conducted analysis to choose between corrective or preventive maintenance. Another example is the use AHP (Analytic Hierarchy Process) along with a sensitivity to carry out analysis for maintenance strategy selection in an Italian oil refinery, as well as the SQC (statistical Quality Control) and decision processes Markov partially observable POMDPs (partly observable Markov Decision processes) for the evaluation of maintenance policies [7].

A new maintenance optimization model is also used to calculate the frequency of failures and downtime as the maintenance data problems applying decision-making grid with fuzzy logic in the maintenance decision.

There is always a variety of criteria in choosing the most appropriate maintenance strategy. Some of these criteria are quantitative such as hardware and software costs, training costs, time between failures, equipment reliability. According to [7], there are also many qualitative criteria that should be considered in the selection of the maintenance strategy, such as safety, flexibility,

labour, high quality of the product. In real situation, because of incomplete or unobtainable information, the data does not contribute, because it has no reliability or is unrealistic, besides that most of this data can be evaluated by human perception and empirical judgement. Therefore, they are generally inaccurate and fuzzy theory can be applied in this problem to analyzed verbal qualitative evaluations.

Diffuse linguistic models allow the translation of verbal expression in numerical terms, thus treating quantitatively with the expression of the importance of various objectives. These quantities can then be used to assess the degree of investment in various maintenance strategies. Many maintenance goals or comparison criteria should be taken into consideration the safety and cost in selecting the appropriate maintenance strategies.

The decision-making methodology can be used for the selection of the maintenance strategy. According to [7], many researchers use multicriteria decision methods (MCDM) for maintenance strategy selection, evaluated the most popular maintenance strategies using fuzzy inference theory and the methodology of MCDM evaluation in fuzzy environment, use past data and technical analysis of process machines and components to identify the criteria for a MCDM problem. They used fuzzy inference system (FIS) to assess the capacity of each maintenance approach.

An example of the inference system analysis applied to a maintenance index is presented in the Figure 1.

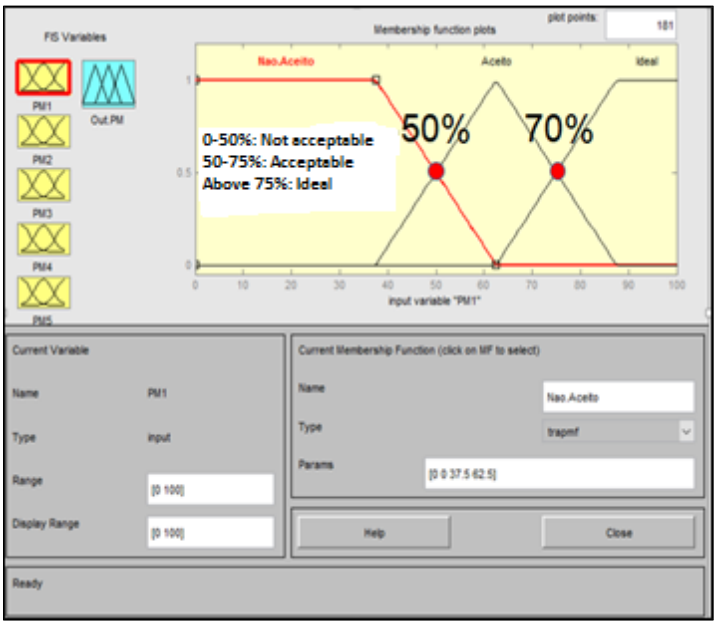

Figure 1: Result of Inference Analysis.
Source:[9].

The fuzzy methodology based on qualitative inputs of verbal evaluation is more practical, because many of the Organization's general objectives of maintenance are intangible. Mechefske and Wang have proposed evaluating and selecting the optimal maintenance strategy using fuzzy linguistics [7].

In this approach proposed, first, the TPM indicators will be prioritized with expert guidance and then the fuzzy modelling is done, for later analysis of the results, then using the fuzzy model and Matlab/Simulink® for interaction with the user, the optimal strategy will be selected using the TPM model.

III. TEST METHODOLOGY

III.1 TRADITIONAL METHODOLOGY

A checklist was drawn up with the main criteria for the eight pillars of the TPM and from the selection of the criteria that pass the blocks of each pillar, it was defined the prioritization within the selection, carried out by maintenance specialists, in order to Make the results more reasonable. In accordance with [12] the eight pillars to TPM are:

- Autonomous Maintenance
- Planned Maintenance
- Quality Maintenance
- Focused Improvement
- Early Equipment Management
- Training and Education
- Safety, Health and Environment
- TPM in Administration/Office TPM

For this purpose, an application based on fuzzy logic was developed to identify threats to the implementation of the methodology and to verify through the analysis of the indicators, the adherence or not of the company the methodology, so that some companies have activities that make this phase viable, otherwise the implementation becomes very aggressive and costly in terms of resources, making it impossible to succeed. Identified these threats it is possible to verify the feasibility of implementation and measures to remedy the gaps and to provide sustainability to the implemented method.

The modelling of the fuzzy system applied in this dissertation followed the same methodology as [13] and was adapted to the TPM context where it was divided into six stages. In the first stage, fuzzy assemblies were built, in graphics, for the discrete (crisp) input and output variables, and the exact values of these variables were inserted in the graphs to obtain the relevance.

The second step consisted in creating the rules of inference. These rules were like, "if condition 1 and condition 2 and condition 3, then output"; Being "condition 1" and "Condition 2" and "Condition 3" input variables (background) and "output" the output variable (consequent).

The third stage consisted of the operation of the fuzzy operators on the background of the rules of inference.

The fourth step applied the method of implication on the consequent rules of inference, the fifth added the results of the rules of inference.

The sixth step transformed the result of the sixth step in the output of the system, producing fuzzy variable, which is indicated in "virtual" panel if the TPM index is acceptable or not.

In step 1, Fuzzyfication of inputs, two phases were involved. In the first phase, the creation of the fuzzy sets for the inputs and outputs of the working hypotheses occurred. In the second phase, inputs were inserted into these graphs, according to the criteria of each variable. The axes of the ordinates are standardized from 0 to 1, by definition of the relevance function and it is possible to re-evaluate the values of the axes of the abscissa.

The second phase was carried out by adding the input of the hypothesis in the graphs with the objective of identifying the respective functions of relevance. The second input produced two different results, with their respective functions of relevance, which denotes the typical characteristic of fuzzy logic, with regard to subjectivity about how much each element belongs to the particular set. Thus, input can be considered an indicator with the relevance of two sets.

Step 2: Inputs are combined into inference rules to produce fuzzy outputs. The fuzzy system inference rules are of the "if-then" type, being divided in terms of background ("if") and consequent terms ("then"). In this modelling, inputs 1, 2, 3, 4 and 5 can take three diffuse results ("Acceptable", "not acceptable" and "Ideal").

It is opted for inference rules that consider the five inputs as background, thus producing 40 different arrangements for the TPM dimension. For the model proposed in this TPM dimension, there is a need to prepare 120 inference rules, with a view to the existence of 3 fuzzy sets for each input variable.

Step 3: Application of the fuzzy operators in the background with the activation of the rules of inference, the operator "E" was applied in the "minimum" mode on the background.

Step 4: The results of the previous step were inserted graphically on the consequent of the inference rules. These inserted relevance produce a graphical surface, which correspond to the inputs of the next step.

Step 5: The graphs resulting from the previous step are aggregated into a single, producing a polygon. In this last step, the polygon resulting from the previous step will be used to produce the output of the system, which will be a discrete variable ("crisp").

Step 6: The most common method to deduct the result of the polygon is by centre of gravity, also called centroid, representing the output of the fuzzy system. In the context of this research, an output of more than "50%" was considered as an "acceptable" TPM indicator and less than "50%" as a "non-acceptable" indicator.

III.2 TRADITIONAL METHODOLOGY

The case study for the application of the proposed indicators and methods was developed in four companies Rio de Janeiro state, with the collection of data, participation of professional's specialists in the area of industrial maintenance in different segments, policies and culture.

These professionals supported the study and accepted the proposal to prioritize questions and answer the questionnaire with the TPM index.

The application of the research in companies "A", "B", "C" and "D" showed consistent results and relevant contribution to the study presented.

With more than three centuries of activity the company "D" is one of the largest company of energy and transmission in the world, multinational of closed capital, with approximately 20 years of activity.

The survey was answered by manager, consultant and maintenance specialists, all with more than 10 years of experience and activity in the function.

The questionnaire is doable for the use of maintenance professionals and involved. The result of data collected where manipulated using Defuzzification and they are presented by centroid, on each pillar and on the output, represented by their values Crisp and normalized through the formula: Normalize = ((x-min))/((Maximum-minimum)) where x is the crisp value, generated after the defuzzification of each pillar, which will be normalized and the minimum and maximum values are the crisp output values, when the forced values of all inputs are minimal and maximum, respectively.

III.3 METHODOLOGY TESTS

The four company's case studies results were analysed with the maintenance manager to confirm and validate the reliability of the results and, to verify their expressiveness in confrontation with the reality of the same.

The diagnosis resulting from the evaluation carried out in each company, in order to validate the method. In this way it was also verified that the number of samples, that of four companies, answered the methodology and achieved the proposed results. The complete responses and results are presented in [9].

The fuzzy system used in this methodology is presented as a Figure 2.

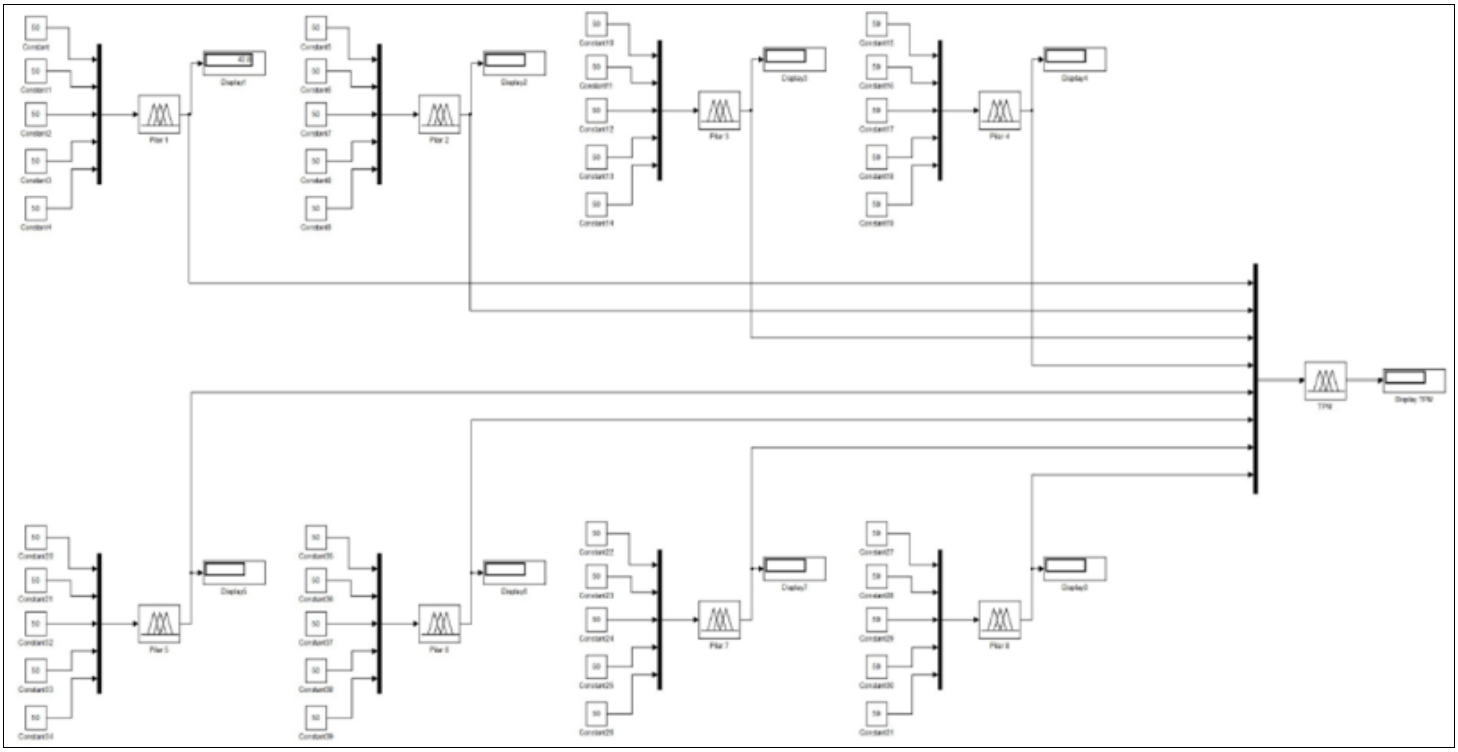

Figure 2: Fuzzy system used in this methodology.
Source: [9].

IV. RESULTS

It follows the explanation of the results, which consists of the diagnoses presented by the application based on fuzzy logic to evaluate the implantation of the TPM methodology, through the values presented in the dimensions of each company cited in the case study, along with the values of the TPM index.

A resume of these results are: the company "A" presented a sustainability index with maturity, as evidenced by the TPM index, whose standard result is 79.71%.

The results observed by the indicators show that the industry presents consistency and efficiency in the pillar safety and environment, followed by maintenance management. A resume of the company "A" analysis is presented in Figure 3.

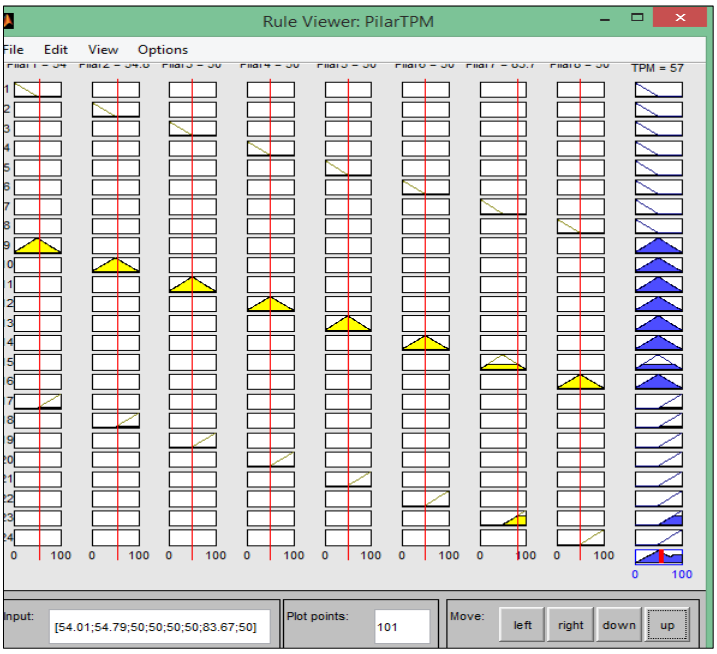

Figure 3: Company "A" responses.
Source: [9].

This value demonstrates the high level of susceptibility of the implementation of the methodology, already adhered to the company, but that offers opportunity of greater efficiency as can be observed through the other indicators and pillars.

Following the company "A", the TPM dimension of organization "B" presents the result 50.81, after being normalized and this result represents 53.45% of adherence to the TPM; the second best compared to the other three cases of study. Although the company has requirements and maturity to develop the methodology and improve the results according to the TPM philosophy, the structure of the company is regimented. The services are run by outsourced companies, with the management of the service and treatment orders with their employees, seeking compliance with the maintenance plan, generated by the contracting company.

Another opportunity for improvement is in controlling costs, which currently are not monitored daily, although there is the management of the maintenance contract by an external organization (as consultant). In general, the company has opportunities and susceptibility to implantation since, there are severe changes and adjustments in the strategic plan of the company and impact of its culture.

The company's indicators "C" confirmed the perception that the company performs several effort measures in the pillar maintenance planning whose crisp index is 50, which represents 50% adhesion.

However, the maintenance management pillar offers great aggression for the success of the methodology presented, especially with regard to the reliability of the maintenance area, whose index is low, 16.33.

Other pillars as total quality/5S and the pillar continuous improvement, also express non-acceptable indicators and all the pillars analysed are below the "acceptable" metric. Accordingly, the normalized TPM index is 20.28% that corresponds to 43.04 "crisp", which represents low adherence to the values and principles that govern the TPM and materializes the failure of the implementation in the studied case. This case, among the four studied, presented less expressiveness.

As mentioned in the previous paragraph, some indicators corroborate the efforts evidenced on the other pillars, even below the "acceptable" metric, and they direct the focus to opportunities for improvement and assist the preparation of the company, through Daily routine changes for implementation, provided there is sustainability in all indicators and pillars.

The pillars "maintenance control" and "maintenance planning" have potential for sustainability and growth, since their indicators have substantial values and will present in a short term, results, mainly for area of Maintenance. Another pillar that needs attention is safety and environment, indicators 1, 2, 3 and 4 are suitable for the "acceptable" metric and 5 is suitable for the "not acceptable" metric; No indicator suitable to the "Ideal" metric. In a more complete view, it is understood that the other pillars can be deployed, paying attention to the fact that the implementation of the pillars individually does not characterize the success of the method, but brings positive results and improvements to the system, provided that there is Discipline, focus and goal of every team and leadership and governance sphere with the aim of maintaining sustainability.

The company "D" has the index of the TPM output, normalized represents 50% adherence to the methodology. Result identical to that of company "B". The total quality/5s pillar has a very low indicator, a result equivalent to the crisp value 16.33, "not acceptable", which anchored the final index, damaging the best results. The other pillars have "acceptable" and "Ideal" index. The training pillar, although it has "acceptable" index, can be improved from the implementation of measures envisaged in the methodology, the increase of the frequency of integration between teams and the elaboration and execution of the matrix of skills.

They are measures that do not generate cost and can be inserted and accepted in the teams in a less complex way.

The Pillar maintenance control system shows an excellence in maintenance management, with expressive result and points to continuous improvement in the other pillars, which also already have well evaluated indicators and suitable to the "Ideal" metric.

While companies "B" and "D" present the same index in the output of the TPM dimension, the results of the pillars are different: while the pillars "safety and "quality" leverages the output of the TPM in Enterprise "B", the "quality" pillar, for example, anchors the output in the case of company "D".

Comparing the results of the companies, it is observed the success of the implementation of the TPM in the company A, which is the best result of the study compared with the result of the other companies.

While company C, it has many opportunities for improvement and action to make planning and effective results and to leverage indicators. This company needs more actions to improve the current outcome, yet there is great potential.

Companies B and D present positive scenarios. Company B, does not have the TPM model deployed, and because it is mixed economy and strong participation of contracted companies, it is justified the absence of some indicators, however there is opportunity for improvements and success of future implementation. Already the company D, is a company that has strong commitment with continuous improvement and shows itself adaptive and great susceptibility of the implementation of the TPM methodology immediately.

IV.1 PROPOSED PROCEDURE

The article proposes the use of fuzzy inference technique aiming at the efficiency and diagnosis of the implementation of the TPM. The specific objectives of this work are:

1. Carry out a study for susceptibility diagnosis and implementation of TPM in the industry;
2. Using the fuzzy system, through a study and bibliographical revision, to make the estimation of non-conformity and measures to solve the problems identified;
3. Develop an application to make the system interface fuzzy with the user and help you develop this specific task in a simple way. It is worth pointing out that application is different from systems software, and its definition is in accordance with the objective of the study and results presented. Given the high cost of an application software, an existing computational model was used that together with fuzzy logic, the user interface was created;
4. Highlight the deficient points of an implemented TPM;
5. Provide a diagnosis of the set of indicators from the inference system.

V. CONCLUSION

This article demonstrates the result of the proposed studies aimed at developing an application, using fuzzy logic to evaluate the implementation of the TPM methodology in the industry, which provides a diagnosis of the set of indicators from the Inference System. These indicators represent the TPM in the company, show whether it has a sustainable basis to support the change of organizational behaviour and from that result, the measures for the treatment of internal processes anomalies are indicated as a means To make possible the susceptibility and reliability of the method.

The modelling of the system and the interface are simple, uses computational program, much used in the academic medium as support tool and analyse the results found from the proposed methodology.

The subject proposed and studied became relevant because maintenance planning causes high effects on manufacturing performance indexes such as production rate, cycle, time, product quality, failure costs is one of the most important problems of Decision, moreover the TPM methodology, addressed in this manuscript, is being deployed more and more in the industries, given the efficiency of the proven methodology.

In addition to verifying susceptibility, the proposed method adds diagnostics to the efficiency of maintenance management by pointing out the pillars or dimensions that anchor the system.

Maintenance, as a system, plays an important contribution to reduce costs, minimizing the downtime of equipment, improving quality, increasing the efficiency of equipment and as a result achieve goals and objectives Organizational and this dissertation proposed an interactive method for evaluating the implementation of the TPM in the industry using fuzzy modelling, in order to contribute to the best selection and strategy of maintaining and achieving the goals.

The methodology used was to first obtain a selection of the questionnaire items used to input the pillar indicators. This checklist was filled out by experts from various business companies, with methodologies employed in their routines that include or not the TPM. From then on, the fundamental variables for the implementation and efficiency of each pillar were defined.

The studies show, through the performance of the indicators, that the culture of a company is linked to the performance of it, through the definition of the routine and discipline so that it is well executed at all levels of leadership, as well as the policy of organization to plot strategic plans, translating into greater success and competitiveness. This means that through the proposed methodology it is possible to evaluate the implementation of the TPM methodology deployed or in the future phase, in the organization, as presented in the chapter results.

They were defined, also at the same juncture, the metrics using theoretical reference and tacit knowledge of specialists. The fuzzy modelling was subsequently made. The use of the intelligent tool, Fuzzy logic, presented success to solve problems, because it represents in mathematical terms, the inaccurate information of the real world. The application efficiently performs the evaluation of the TPM deployment in the industries and through the results presented, demonstrates the reliability of the selection of the indicators for the dimensions of the TPM pillars, which were used in this study as input for the fuzzy inference system.

Finally, by applying the proposed method for determining priorities and identifying weaknesses it is possible to define whether the implementation will succeed or not, and what actions can help strengthen the basis for implementation.

It should be clarified that the proposed methodology can be support to the specialists of Maintenance Management diagnostics in the identification of the profile of each company in evaluation, but cannot be unique. The interviews were carried out with a single company manager, and it is understood that for a more thorough evaluation, other managers (at different levels of responsibility) can participate so that a more global view of the process can be effectively Understood and the answer to be realistic.

It is important to stress that the implantation of the TPM must reach all hierarchical levels of the corporation, thus justifying the extension of the application of the methodology to other managers.

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RESEARCH ARTICLE OPEN ACCESS

ANALYSIS OF AN AUDIT AND EXPERTISE IN A CIVIL CONSTRUCTION COMPANY LOCATED IN THE CITY OF MANAUS/AM

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ABSTRACT

This article aims to emphasize the importance of Auditing and Expertise with civil construction companies, as well as to investigate whether Internal Audit systems can be considered as a tool in management procedures. Due to the fact of the constant growth in the last years of the companies are linking the concept of Strategic Management to the existence of a specific branch of the new administration, which reflects in the main objective that is to know the biggest obstacles that deprive the companies of civil construction to adopt the audit as a management tool for the purpose of ascertaining the procedures adopted by company managers. For this, a comparative analysis was performed between the literature review and the opinion of the managers of the organizations, through semi-structured interviews. The research problem was adopted qualitatively using books, articles, dissertations, legislations and manuals to support the analysis of the contents from 2009 to 2019. Finally, there is a need for transparency in procedures. In this context, there are tools available to organizations for systematic use. In this sense, Internal Audit should be understood as a Strategic Management instrument that completes the objective, systematic and periodic assessment of companies. This tool can and should be extended to the entire organizational structure of the company. In other words, it can be stated that Internal Audit procedures aim to ensure the financial protection of an organization through correct accounting practices.

Keywords: Strategic Management, Audit and Planning.

I. INTRODUCTION

Every year, new companies appear in Brazil, from the most varied market segments, driven, in part, by the entrepreneurial spirit of the Brazilian Provo, in part, by the unemployment wave that has been plaguing the country for some years, as a result of disastrous economic policies of the government, literally pushing those who lost the stability of the guaranteed salary at the end of the month into a business of their own.

According to statistics released by SEBRAE for the year 2015, it reveals that 98.5% of the private companies operating in Brazil are micro and small, which represent 27% of the Gross Domestic Product, 54% of the total jobs with a formal contract, 44.1% of the mass of company wages and 61% of the number of exporting companies [1].

Within this scenario, the importance of the theme of this research is due to the fact that, according to statistics prepared by a serious and competent entity such as SEBRAE, which were presented above, civil construction companies are the ones that drive the economy of the Brazil. Given this observation, it is assumed that the absence of a strategic direction guided by a body such as Audit can lead the organization to face serious problems - this when it is not involved in more serious and even irreversible situations, such as losses caused to society , heritage, the environment and the current economic order, among others.

Considering that a company's strategic decisions are commands that can lead it to success or weakness, it is naturally obvious that they cannot be taken at random, much less without safe and consistent guidelines. Therefore, it is the manager's obligation to surround himself with accurate and reliable

information that aims to guide him safely amid the uncertainties of the environment.

It is notable that in large companies, Auditing is the executive advisory body whose existence has no other reason than to subsidize the manager in decision-making. The purpose of these staff members in the structure of large organizations is justified by the relevance of the information they produce whose benefits far outweigh the high costs they represent.

In view of what has already been said, this study points out that the Audit area must integrate with all sectors of the organization, as it is the one that receives, consolidates and transforms data into information. As a consequence, the Audit must manage corrections and changes when necessary in order to always seek the best results. In summary, it is argued that the Audit is responsible for monitoring key activities in the company, such as: accounting, costs, tax, asset control, risk control, information management. In view of the above, the problem that is proposed to research and respond through this work is due to the following doubt: What are the obstacles that prevent civil construction companies from adopting Auditing as a management tool?

This study assumes the objective of knowing the greatest obstacles that prevent civil construction companies from adopting Auditing as a management tool, despite the well-known benefits that this advisory body brings to large companies. The specific objectives are to: conceptualize Audit in companies; analyze how managers can use the information generated by the Audit to make decisions; and, finally, to present the most important performance indicators for managers of micro and small companies.

Finally, it is emphasized that the importance of this research increases when it is known that in large companies the work of the Audit is usually taken very seriously, considering that their studies and guidelines significantly influence the decisions of managers.

II. DEVELOPMENT

The Audit comprises the organization's plan and all the methods and procedures used to safeguard assets and property [2]. It can be seen, then, that internal auditing of an accounting nature encompasses all the systems, methods and procedures within the company in which they are used within the various sectors with the purpose of safeguarding the assets of companies such as: assets, rights and obligations, such as also, the verification of all accounting records of the company, in order to assess whether they are duly correct [3].

The control corresponds to the function that gave rise to the Audit. Based on a historical context, it has been said that “at the time of its emergence, the main objective of Audit was to carry out centralized and rigid control over large corporations, their subsidiaries, branches, departments and divisions spread across the United States and other countries” [4].

However, the changes verified in the corporate environment and with the Audit evolution itself, made it incorporate other attributions, supporting the organizations' management process in order to lead them to meet their objectives. However, the Audit's attributions have overcome the control aspect as a fundamental function, there is no doubt that this is one of the pillars of the performance of any Controller [4]. Among the basic functions of Auditing with construction companies, we can highlight planning, control and accounting.

In this sense, the Audit is responsible for observing the executions of the tasks that happened correctly, according to the planning, and it is up to him, the auditor, the task of correcting errors, both in the planning process, as well as in the process of execution within the works.

Although an appropriate organizational plan will vary with the type of company, a satisfactory plan generally needs to be simple and flexible and should lend itself to establishing clear lines of authority and responsibility. An important element in any organizational plan is the structural independence of the operations, custody, accounting and internal audit functions. The responsibility and the corresponding delegation of authority must be clearly defined and placed in organizational charts or manuals [5].

Conflicting and duplicative responsibilities should be avoided, but where the work of two or more divisions is complementary, responsibility can be divided into phases. These divisions of responsibilities are inherent in a good internal audit, which stipulates that the tasks of initiating and authorizing an activity are separate from those of its accounting [3]

In order to understand the importance and need of the Audit with the civil construction companies, in all its managerial extension, there is the management of the costs of the work, which allows the classification and control of costs, the formation of the sale price and the verification how much each project contributes to the company's profit [6].

Thus, the Audit, as well as other areas of the company, must work to capture information from the external and internal environments for the analysis of threats and opportunities and the weaknesses and strengths of construction companies, in order to streamline the guidelines strategic. For each stage of the “planning, execution and control” cycle to be effective, it is necessary that this process be supplied with timely, correct and reliable information to assist managers in decision making [7].

Within this context, it is added that, with the defined weaknesses and threats, it is possible to determine strategic guidelines, with the objective of providing improvements in the exposed environments and that express the managers' perspectives for the next and even next month’s years [8].

For the Audit to adequately reflect the organization's transactions, it must be supported by supporting documents provided by the other areas of the company. The latter must also be supported so that the information presented there is reliable, and, above all, controllable. Accounting can act as a supervisory body, checking whether internal controls are being carried out [1].

Finally, having a global view of the company and not only worrying about issues related to compliance with tax authorities, legal regulations, as well as raising funds and looking for investments with adequate returns. The Audit aims to generate information that facilitates the decision-making process, collaborating with managers in the task of achieving organizational effectiveness [9].

III. MATERIALS AND METHODS

To choose the theme, it was observed the need to contextualize the relevance of auditing with civil construction companies, and the assumptions that surround it, about this scenario: the first step for someone who proposes to develop a monographic work is choice of subject. Even with a vast field to research, it is common to face the doubt of what to choose for the study [...]. Therefore, there is a tendency, at first, to choose a very broad and generic subject. Thus, it is necessary to find something more specific and punctual that can be searched. In this work, the deductive method was used, which aims to help the formulation of guiding questions and their confirmation [10].

Still within the methodological context, the principle of this study was qualitative research, in order to clarify which

accounting techniques will be used in an Audit, explanatory theoretical support is needed, clarifying which are these accounting tools, which characterizes the choice by the qualitative method.

In general, this article is characterized as a qualitative research developed through a case study, with the purpose of understanding and explaining the importance of auditing with construction companies. This context provides a rich empirical material, as it presents a conjuncture of great transformations for the entity where the case study was adopted.

IV. STUDY APPLICATION

The questionnaire can be a good data collection tool, which presents a set of questions that are answered by the respondent, the form being another data collection technique in which the researcher establishes previously formed questions and writes down the answers. In all, 10 semi-structured interviews were carried out with the company's employees. In this stage of the elaboration and application of the questionnaire on the importance of Auditing within the organization, the typology of exploratory research was used [11]. During the questionnaire, the author used non-participant observation, valuing ethics in carrying out this stage of the research.

The research sample is composed of its managers and collaborators. The representativeness criterion assigned to determine the sample was that of companies that have been selected by the author of the study. Thus, the selected sample can be classified as non-probabilistic, and the selection was made by accessibility and typicality, where the researched elements are considered representative of the target population [12].

Based on the interview, it was observed that the average age of employees is between 24 and 29 years old, which means that they are young graduates, who have been working in the labor market for less than 5 years and all have some graduate lato sensu. The interviews lasted, on average, 26 minutes, totaling 3 hours and 29 minutes of recorded audio, as shown in Table 1.

Table 1: Profile of the interviewees.

	JOB ROLE	SERVICE TIME	INTERVIEW MODE	DURATION
E1	Manager	11 years	Presential	00:28:15
E2	Treasury Department Manager	5 years	Presential	00:32:35
E3	Financial analyst	5 years	Presential	00:24:19
E4	Administrative Assistant	2 years	Presential	00:22:39
E5	Administrative Assistant	8 months	Presential	00:19:58
E6	Secretary	1 year	Presential	00:36:42
E7	Accounting Assistant	2 years	Presential	00:21:25
E8	Technical Analyst	3 years	Presential	00:24:04

Source: Authors, (2019).

A basic interview guide was used in a flexible and differentiated way, according to the interviewees' understanding. Every time it became evident that important issues were not being addressed, changes were made to the guide, whereas if a subject proved to be irrelevant, it was discarded, with the possibility of being recovered later. An annotation book was used as auxiliary resources.

V. RESULTS AND DISCUSSIONS

The next step was to extract the meaning of the data, from the comparison of the results found with the literature to elaborate the conclusion. It was observed immediately, and that the company object of our study, carries a heap of provision of services to other companies in general located in the city of Manaus / AM. According to the speech of the financial manager: “a great differential present in the organization is the high level of customer satisfaction, which has enabled the company to build over the years a solid relationship and qualified contacts in the main undertakings in the city (E1)”.

In this line of reasoning, this study argues that organizations today have invested a large part of their resources in technology, aiming to modernize production. Faced with this context, it is necessary to understand that for each new resource focused on productivity, there must be someone who puts this “machine” in operation, within this context comes the importance of Leadership, which in a succinct way, can be understood as a social phenomenon, because it occurs in social groups and for social groups.

Within this context, this study will bring a small sample with the most relevant answers, from the interview about the relevance of Internal Audit. When asked about the knowledge about the procedures on Internal Audit, it was noticed that the interviewees in their entirety claimed to know the procedures of this accounting tool. The next moment, he was asked about the importance of Internal Audit within the company, where the following notes were obtained:

“Internal Audit can be considered one of the most important tools to be worked on within a company (E3”).

“It is necessary that every company, has an Internal Audit sector, in its facilities (E4”).

“The development of a specific Internal Audit sector can bring numerous benefits to the company (E8”).

Following the interview, it was asked whether the company makes use of the Internal Audit tools within the company, everyone said, no. Based on this result, a question was asked about which tools could be used for Internal Audit that could be used in the Company.

“Planning (E1, E5, E6 e E8”).
“Critical analysis (E1, E4, E5, E7 e E8”).
“Preparation of a Manual (E3”).

The next question relevant to the study addressed the decision to implement a specific Internal Audit sector at the company's facilities. In this regard, parts of the employees showed interest in having an Internal Audit sector, not only within the specific department, but within the company. Following the descriptions about the installation of an Internal Audit sector in the company, the following answers were obtained:

“An Internal Audit sector will bring numerous benefits to the organizational processes of the sector where I work (E3)”

“There will be a great improvement with the implementation of the Internal Audit sector in the company (E7”).

‘‘An Internal Audit sector would make fewer process errors and bring to the company a reduction in construction production costs, mainly in the purchasing sector, I believe (E7)’’

“[...] the Internal Audit sector will improve the organization and standardization in the sector (E8”).

Based on the aforementioned discourse, it is observed that the implementation of an Internal Audit sector within the organization will bring numerous benefits, as the organization of

the internal processes of the organization's departments may rely on the standardization of work, as well as operational procedures, established by the managers.

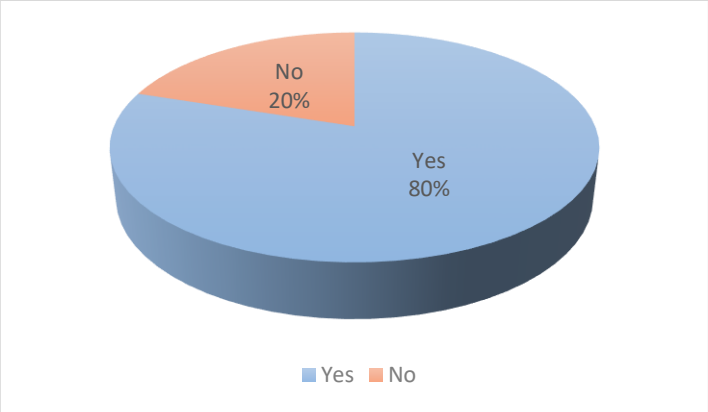
In the next moment, the managers of the company were asked whether they consider the company to have any type of internal control? The purpose of this questioning was to find out if in the company, there was any control in the organizational process. In this particular 80% (n = 6) of the interviewees stated that they work in a certain way, with the tools of the Internal Audit Graph (01), as follows the speech of some:

I do my own control in the company notebook (E4).

The accountant already works with this here at the company (E7).

I do my control with the help of the computer (E8).

Graph 1: Knowledge about the Audit tools.



Source: Authors, (2019).

In this regard, it is commented that every company needs to have strategic and financial planning, the objective of which is to maintain its effectiveness in its actions, as its data must be correctly transposed to the company's management. Continuing the interview, another question that was relevant to the study was: Does the company use financial and operational planning reports to make decisions?

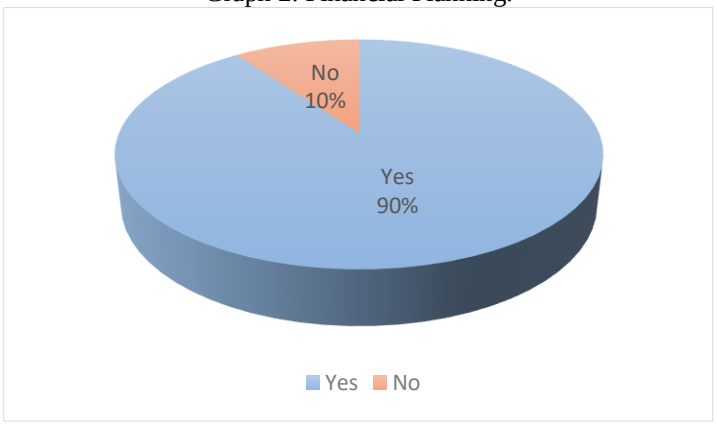
In view of this questioning, 90% (n = 7) of the interviewees stated that they work with financial planning and engineering projects for decision making, as can be seen in Graph 02. Giving greater emphasis to the positioning of this decision, they had the following speeches:

My financial and planning sectors are the heart of my company (E1).

[...] in the face of the crisis faced by the country, it is necessary that every entrepreneur be aware of his financial resources (E7).

Brazil is in crisis so ‘‘prevention is better than’’ (E8).

Graph 2: Financial Planning.



Source: Authors, (2019).

Financial Management is fundamental for companies to be successful and sustainable, seeking perpetuity, this management focuses on the study of financial decisions taken in the company [13]. Where the Company can be defined as being: A hierarchical human group, which mobilizes human, material and financial resources to extract, transform, transport and distribute products or provide services and which, in accordance with the objectives defined by a management, interferes with different hierarchical levels. the motivations of profit and social utility [14].

The increasing complexity in the business world also determined that the person responsible for the financial area should develop a more integrative vision of the company and of the relationship with the external environment [15]. Within this new context in which organizations are inserted, that is, within a highly competitive scenario, the entrepreneur must be aware of these basic business functions, and must analyze, plan and control the use of financial resources in making investment decisions and future financing.

In the following moment, the Audit activities related to the Accounting function and Project Planning were questioned, through the following questions (Table 02):

Table 2: List of Audit and Accounting.

QUESTIONING	**Answers(%)**				
	Does not occur	Occurs in some more elaborate activities	Occurs in some deadline activities	Occurs only in monitoring / management	Occurs on execution
In relation to accounting and planning activities, and does the involvement of audits happen?	10	0	60	20	10
In the preparation of balance sheets and other accounting items required by the legislation and new projects of the company, do they involve Internal Audit?	0	10	0	80	10
When generating management reports with information usually required by the company's top management, is there an Audit involvement?	20	0	10	70	0
In the development of business policies and procedures, is there an Audit involvement?	30	40	20	10	0

Source: Authors, (2019).

In view of what was mentioned in the previous table, this study observed that 60% (n = 5) of the interviewed companies stated the existence of a relationship between the activities of Auditing, Planning and Accounting, and that these occur in the monitoring or management of actions business (80%), mainly in the generation of management reports with information usually required by the company's top management (70%), a small part (40%) makes use of Audit in the development of business policies and procedures.

Facing this scenario, this study stresses that business managers must be aware of some basic functions for the performance of the job, among which we can highlight: Analysis, planning and financial control; Investment decision making; and Financing decision making.

This task is even more fundamental for medium and small companies, as it is competing directly with large companies in the market, "to guarantee survival it is essential that the micro enterprise be structured internally, adopting a management model that provides the division of tasks properly, otherwise, it can result in business failure. The need to build an internal environment capable of guaranteeing each participant the proper understanding of the role in the production process, is essential for the business to establish itself and guarantee a profit" [16].

The panorama of the relationship between the Audit, Planning and Accounting, raised the relevance of the following question: Does the Audit analyze the information provided of an accounting, equity, operational, economic, financial and non-financial nature related to the management process? Faced with this questioning, 70% (n = 8) stated that this relationship occurs in some more elaborate activities.

According to this opinion, it is argued in this study that the implementation of the Audit allows a systematic, global and integrated view of the company's operational performance to the manager, transposing the Strategy into concrete objectives and actions, allowing not only to evaluate the ongoing process but also to update it, when necessary, the strategies adopted.

Financial statements are prepared and provided to stakeholders, and their understanding is directly linked to social, economic and legal factors, which differ from one region to another [16]. The technique of preparing the financial statements influences the promotion of accountability and planning by the administrators, and that the information from the accounting is not restricted only to the income statement and the balance sheet, it provides an uninterrupted flow of information on the most different factors corporation management [16].

For this reason, it is clear that the strategy, vision, mission, objectives and goals must be aligned with the indicators created by the Audit. Ultimately, this study points out that most of the questions in this question were not answered by the managers, as there was no strategy for auditing in the company [17].

Finally, Audit stands out as an efficient tool, however its alignment with the strategy is fundamental for its successful implementation. The information collected demonstrated how the Audit is functional even before its implementation is completed, differentiating the organization from its competitors, standardizing its processes and favoring a global view of the company.

VI. CONCLUSIONS

In response, to the questioning of this study: it consisted of the following question: What are the obstacles that prevent civil construction companies from adopting Auditing as a management tool? This study argues that even though there is much more awareness of the relevance of Auditing today, in many companies this idea is yet to be implemented.

Based on the concept of Audit, argued during the conduct of this study, it can be said that the good news is that, in general, the concept of Audit has been gaining much more space in organizations of all activities and sectors. Another evolution that should be highlighted focuses on the relevance of the effectiveness of the Audit, as this proves to be a powerful tool in Business Management, especially in terms of fraud prevention.

The professional responsible for the Audit must follow a plan, which was conceived by the company's management, in this particular, it is argued that it is the duty of this professional, to demonstrate through the control the bottlenecks of the execution of tasks. In this sense, it is pointed out that the first step should be the structuring of a strategic plan, where it must contain all the variables that may in some way influence the results of the Audit.

In this sense, the Audit must be understood by micro and small companies, as an instrument of Strategic Management that completes the objective, systematic and periodic evaluation of the company, this tool can and should be extended, to the entire organizational structure of the company. In other words, it can be said that the Audit procedures aim to ensure the financial protection of an organization, through correct accounting practices.

Therefore, this study makes the suggestion to implement Audit in civil construction companies, considering the benefits, which are very significant, reflecting both internally in the operational organization and externally in the context of the company's positioning in the market. In this sense, this study comes to an end, highlighting that with the completion of this study it was evident that the implementation of an Audit sector in companies, brings with it significant changes in the traditional existing relationships between members of the organization.

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