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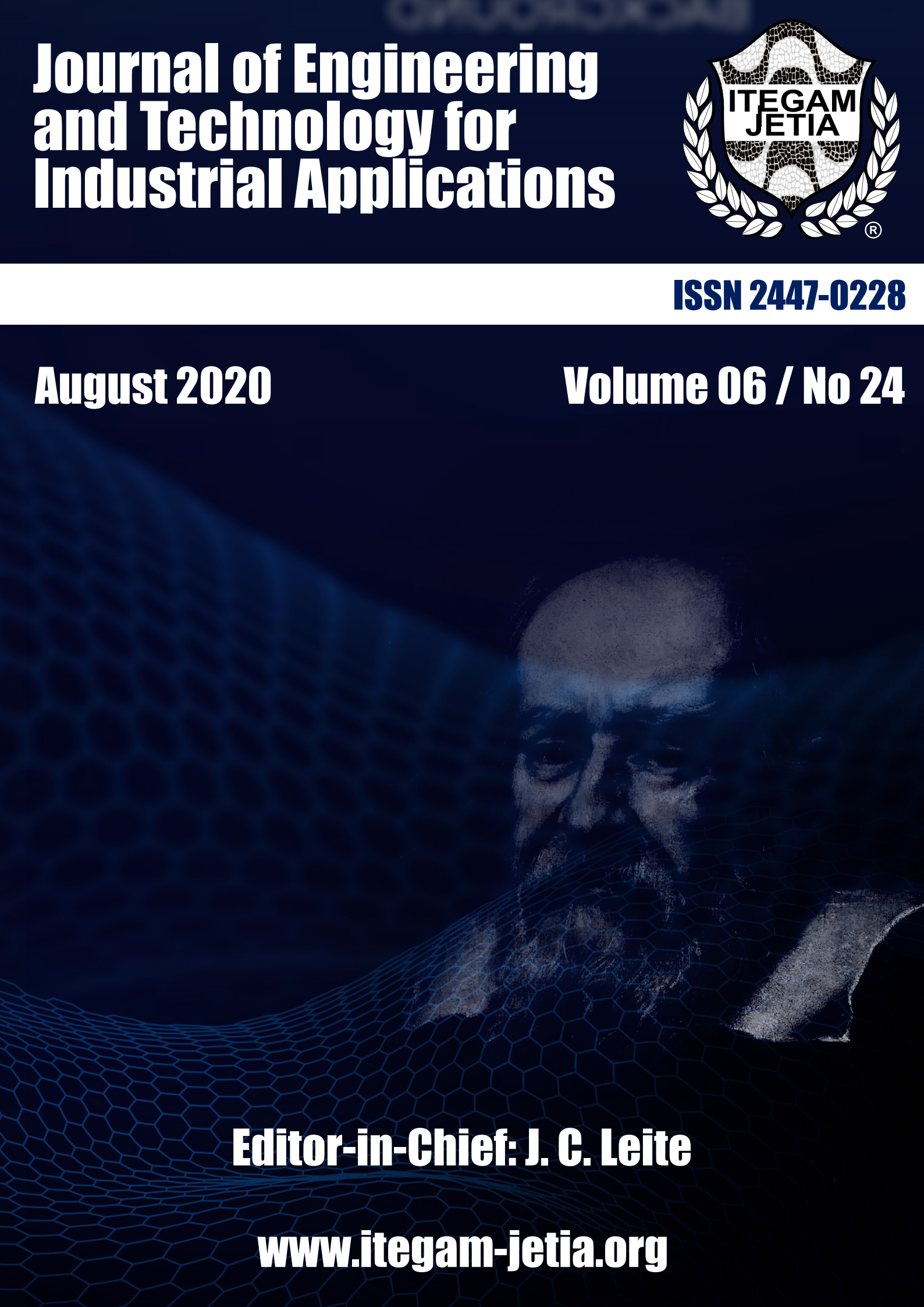

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Galileo Institute of Technology and Education of the Amazon (ITEGAM).

Joaquim Nabuco Avenue, No. 1950. Center. Manaus, Amazonas. Brazil.
Zip Code: 69020-031. Phone: (92) 3584-6145.

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SUMMARY

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RESEARCH ARTICLE OPEN ACCESS

BIOMATERIALS AND ESSENTIAL OILS AS PROMISING TOOLS FOR PUBLIC HEALTH PROBLEMS IN BRAZIL: PRELIMINARY STUDY

Joab de Souza Arouche[1]

[1] Federal University of Amazonas – UFAM. Manaus–Amazonas, Brazil.

[1]http://orcid.org/0000-0002-4254-0529

Email: arouchejoab16@gmail.com

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ABSTRACT

Biomaterials have been applied for a long time in different areas and, for countless uses and with technological advances, they have helped to solve several problems in the most diverse areas of health, working on the development of different mechanisms, orthoses, prostheses. and, in recent years, in the creation of formulations for the biological control of microorganisms that cause public health problems. Brazil is among the countries that have the most cases of diseases transmitted by arboviruses in the world. There is scientific evidence reporting the use of plants with repellent and bioactive properties for the development of natural, non-toxic and efficient alternative products. Develop a biodegradable polymeric formulation containing encapsulated essential oil, and test the essential oil of *Piper callosum in natura* on larvae of *Aedes aegypti* mosquitoes. The formulation developed and submitted to 35 °C was stable in all evaluations during the 25 days of analysis and the essential oil of *Piper callosum* proved to be a promising natural resource against larvae of the mosquito *Aedes aegypti*.

I. INTRODUCTION

Biomaterials have been applied for a long time in different areas and, for countless uses and with technological advances, they have helped to solve several problems in the most diverse areas of health [1], working on the development of different mechanisms, orthoses, prostheses and, in recent years, in the creation of formulations for the biological control of microorganisms that cause public health problems [2].

The Brazil is among the countries that present the majority of cases of diseases transmitted by arboviruses in the world, mainly the population of the State of Amazonas [3], with high rates of diseases transmitted by the *Aedes aegypti* mosquito. The great proliferation of *Aedes aegypti* in northern Brazil is associated with the tropical and rainy climate that favors its reproduction.

The zika, dengue and *Chikungunya* viruses are responsible for the majority of public health epidemiological problems; however, in recent years, scholars have invested in the development of natural strategies for possible biological and epidemiological controls of arboviruses, aiming at the use of essential oils extracted from plants in the Amazon. There is scientific evidence reporting the use of plants with repellent and bioactive properties for the development of natural, non-toxic and efficient alternative products [4]. The chemical constitution of the essential oils (EO) of certain plants varies according to their species and their biological activities are related to the constituents and functional groups [5]. For this reason, some of them may have specific insecticidal, fungicidal, acaricidal and bactericidal functions. These functions are exploited for the development of new biocidal formulations.

The plants that are part the *Piperaceae* group, in addition to being major producers of essential oils (EO), are rich in bioactive substances. Among these species, *Piper nigrum*, *Piper aduncum*, *Piper hispidinervum* and *Piper marginatum* stand out, which proved insecticidal and larvicidal activities [6,7]. Essential oils from certain plant species have numerous biocidal activities [8,9], antioxidant, antimicrobial and antibacterial functions [10], in addition to fungicidal properties [11].

The Amazon has one of the largest ecosystems in the world, with a wide variety of plants rich in EO (essential oils) with bioactive and medicinal functions [12]. *P. callosum* is the largest genus in the family *Piperaceae* [13] and is widely distributed in the north of the country. This species is a perennial

shrub, with twisted stems and branches, alternating permanent leaves on the central face and has small yellow flowers. In addition, it has a predisposition for hot climates and soils rich in organic matter, justifying the fact that it is widely found in the State of Amazonas.

In the northern region of Brazil, *Piper callosum* is known as 'electric oil' because it provides immediate relief from muscle pain (analgesia) and is also used in folk medicine to combat stomach pan and relieve the inconvenience of insect bites [14]. The essential oil of *Piper callosum* is composed of monoterpenes, sesquiterpenes, phenylpropenes and terpenoids. Figure 1. *Piper callosum*.

Figure 1: *Piper callosum*.
Source: Author, (2019).

Biodegradation involves a natural process in which polymers are converted into simpler compounds, because, according to time and/or temperature, structural properties deteriorate. In recent years, nanotechnology has enabled the use of natural materials for the development of biosystems with multidisciplinary applications. Most researches use gelatin as a base material for encapsulating certain assets, such as medicines, oils and products of biological origin. Among the synthetic polymers most found in biotechnological applications, polycaprolactone stands out. Due to the fact that essential oils have volatile substances that are easily lost when exposed to certain temperatures and environments, it is necessary to develop techniques capable of conserving assets so that their properties and functions do not change. For this reason, the essential oil of *Piper callosum* was encapsulated by means of gelatin and polycaprolactone. As gelatin and essential oil are elements that undergo metamorphosis when exposed to certain factors, the biocide stability study was carried out for 25 days at less than 35 °C to verify the stability parameters according to the storage time and temperature. This temperature was chosen based on the climate of the Amazon, which revolves around 32 °C and 36 °C.

To develop a biodegradable polymeric formation on a nanometric scale containing encapsulated essential oil; evaluate the stability of the biosystem as a function of the preservative and temperature considering the parameters of encapsulation efficiency, pH, turbidity, electrical conductivity and organoleptic properties for a determined time, in addition to performing the larvicidal test applying the essential oil of *Piper callosum* in natura to mosquito larvae *Aedes aegypti* to teste the effectiveness of the natural asset.

II. MATERIALS AND METHODS

Two different solutions were prepared for the synthesis of gelatin/polycaprolactone nanoparticles. Solution 1: (1g) od gelatin was solubilized in (100mL) od distilled water and heated to 50 °C with constant stirring. Then, (0.30g) of tween 80 solubilized in 50 mL of distilled water, after solubilization it was poured into the solubilized gelatin. Solution 2: (0.05g) Polycaprolactone, (0.02g) Span 60 and (0.1g) TACC were solubilized in (5mL) dichloromethane. 0.0750g of *Piper callosum* essential oil (EO) supplied by the Brazilian Agricultural Research Corporation (EMBRAPA) was added to Solution II. After the solubilization of the essential oil, solution II was added to solution I using the turrax nanoparticle disperser for 30s. Then, (0.0935g) of the enzyme transglutaminase was added to the final solution, together with the preservative NE. The formulation was stored in the incubator for analysis, the following evaluation parameters were used: encapsulation efficiency, turbidity, pH, electrical conductivity and senses (sight and smell) for the study of organoleptic properties, Figure 2. Formulation development illustration.

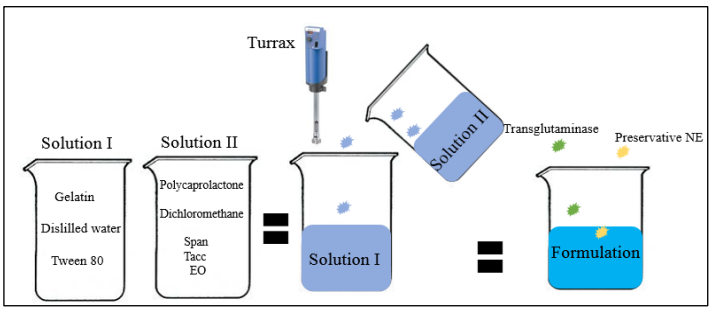

Figure 2: Illustrative image of the development of the formulation.
Source: Author, (2019).

The larvicidal test was performed at the Malaria and Dengue Laboratory/LMD-CSAS (INPA) to test the effectiveness of the essential oil of *Piper callosum in natura*, groups of 10 larvae in the 3rd larval stage were inserted into plastic cups (100 mL) containing initially 1mL of distilled water, 100µL of the larval food and 100µL of the larvicidal concentrations (72 to 48 $mg.mL^{-1}$) (47 to 35$mg.mL^{-1}$) of the essential oil solubilized in DMSO. Readings were taken after 24 and 48 hours of exposure; larvae that did not respond to artificial stimuli were considered dead.

III. RESULTS AND DISCUSSION

III.1 STUDY OF FORMULATION STABILITY

After 25 days of studying the behavior of the biocidal formulation submitted to 35 °C and containing the preservative NE, we obtained the following results: Figure 3. Encapsulation efficiency (EE), Figure 4. pH, Figure 5. Electrical conductivity, Figure 6. Organoleptic properties and Figure 7. Turbidity.

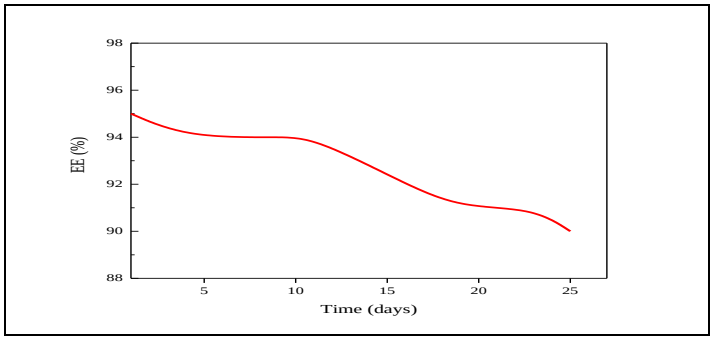

Figure 3: Encapsulation efficiency (EE).
Source: Author, (2019).

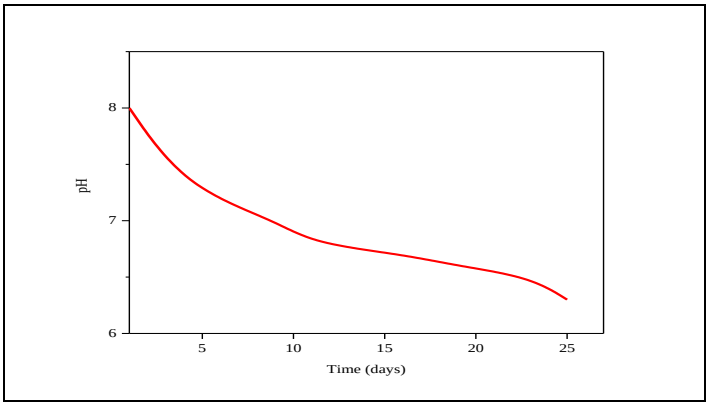

Figure 4: pH.
Source: Author, (2019).

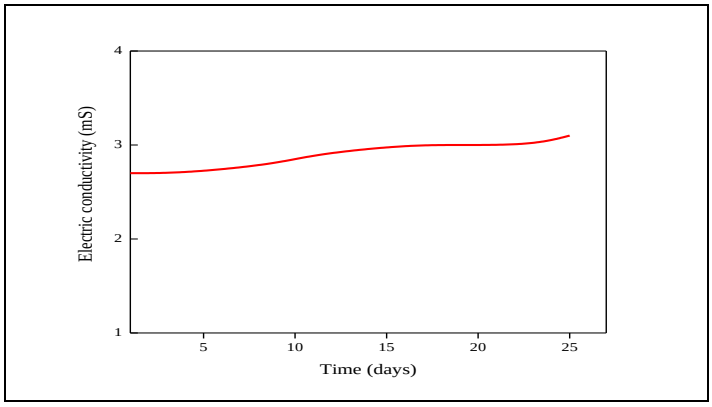

Figure 5: Electrical conductivity.
Source: Author, (2019).

The formulation showed an EE greater than 90%, indicating that the combination of gelatin and polycaprolactone encapsulants was effective in encapsulating the essential oil of *Piper callosum*. The initial value of the encapsulation efficiency (Figure 3) was around 95% and after 30 days of evaluations 90%. Polymeric biocides are considered efficient when their encapsulation efficiency is greater than 70% [15]. If we consider only the analysis of the encapsulation efficiency (EE), the formulation would indicate stability, since the encapsulation efficiency was shown to be high. For this reason, it is important to associate the stability assessment with other analyzes (such as turbidity, organoleptic properties, pH and electrical conductivity). Some studies report that biodegradable polymeric formulations that have two layers are more resistant to extrinsic factors than those that have only one [16,17].

During the 25 days of analysis of the stability of the formulation, the pH values decreased, but remained above 6.3. Based on this result, it can be said that the EO remained protected by the gelatin and polycaprolactone layer during the evaluation period. The pH was adjusted to 8 so that its behavior over time was studied and, after 25 days, it dropped to 6.3. As shown in (Figure 4), the formulation showed a decrease in pH over the 25 days of study, however this value did not compromise the formulation, as the pH of the essential oil of *Piper callosum* is around 5.5. This fact is related to the exposure of the EO to the environment by decreasing the EE, as previously seen, a single isolated evaluation is not enough to analyze the stability of a formulation, therefore, it is necessary to join several evaluation parameters to determine the effectiveness of a product.

The decrease in pH values is not only related to the exposure of the EO to the medium, since the pH of the OE is acidic and, naturally, when exposed to the medium, the formulation will tend to the pH of the essential oil. The electrical conductivity values were in the range between 2.7 and 3.1 mS, as shown in (Figure 5). These values corroborate the EE and turbidity assessments. Because unexpected changes in electrical conductivity are indicative of instabilities [18].

The increase in the electrical conductivity values in systems containing EO encapsulated in biodegradable polymeric nanoparticles is related to the presence of a large amount of free charge (ions) in the solution and, consequently, to the reduction of the encapsulation efficiency and to the destabilization of the formulation. In some cases, these electrical conductivity values can be changed even further, depending on the temperature at which the formulation is packaged. The decrease in pH values can be correlated with the values of electrical conductivity, since this decrease is related to the exposure of greater amounts of EO in the medium and, consequently, to the increase in charges [19]. The electrical conductivity values of the formulation did not compromise its stability.

The organoleptic properties (color and odor) were analyzed in comparison with the initial aspects of the formulation. The purpose of this evaluation was to verify whether the formulation suffered changes in color and odor, in addition to phase separation, excessive turbidity and interruptions. Regarding organoleptic properties, the formulation did not show any significant changes that would compromise pain and appearance. As shown in (Figure 6). Corroborating with the indications found by the evaluation of the organoleptic properties of the formulation, the turbidity was not excessive (Figure 7), pointing out that the materials used for the development of the formulation were not compromised, although we know that biodegradable systems are easily compromised by external factors (chemical, physical and biological) [20].

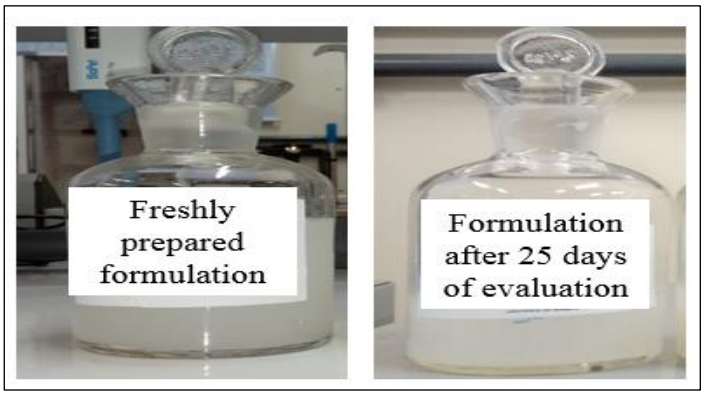

Figure 6: Organoleptic properties.
Source: Author, (2019).

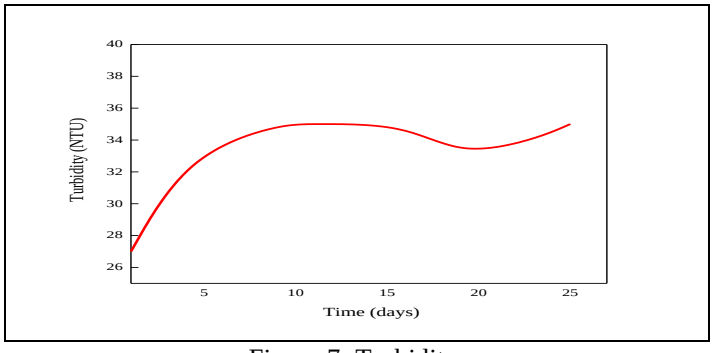

Figure 7: Turbidity.
Source: Author, (2019).

III.2 LARVICIDAL STUDY

The bioassays performed with the essential oil of *Piper callosum* showed greater activity in the first 24h of exposure, with low increases in the mortality percentages after this time interval, as shown in Table 1.

Table 1. Values of LC_{50} (inhibitory concentration) and CL_{90} (lethal concentration) of the essential oil of *Piper callosum in natura* against *Aedes aegypti* larvae.

Species	Time (h)	LC_{50} ± DP (µg. mL^{-1})	(LCI-LCS)	LC_{90} ± DP (µg. mL^{-1})	(LCI-LCS)
Aedes aegypti	24	53.46 ± 1	52.1 -57.9	94.15 ± 1	87.4 – 124
	48	38.13 ± 1	37.4 – 40	55.96 ± 1	53.3 – 67.2

Upper confidence limit (LCS), lower confidence limit (LCI) and standard deviation (SD).
Source: Author, (2019).

Through the applied doses, the values of lethal concentrations CL_{50} and CL_{90} were found through analysis by the POLOPC® program (LeOra Software Berkeley, CA), respecting the confidence interval at the 95% significance level. The larval toxicity study showed that the essential oil has greater larvicidal activity in the first 24 hours. Considerable lethal concentrations were (53.46 ± 1) and (94.15 ± 1) µg.mL^{-1} for LC_{50} and LC_{90}, respectively. However, the activities recorded in 48 h were essential to complement and prove the effectiveness of the essential oil of *Piper callosum* against the larvae of the *Aedes aegypti*. Normally, in the first hours of biological tests, the target organisms have higher mortality, in the following hours the effects are less, but more extensive [21].

P. callosum oil showed larvicidal activity from the concentration of 48 ppm in the first 24h. However, larval mortality was representative only from the concentration of 72ppm. The mortality percentages were quite different between the concentrations used, in the first 24h of the experiment, with a gradual increase in the mortality percentage as the concentration was increased.

IV. CONCLUSIONS

Using the results as a basis, we can say that the essential oils of certain species in the Amazon have biocidal activities, however, we emphasize the essential oil of the *Piper callosum* plant, which has been shown to be very effective against *Aedes aegypti* larvae.

The biocide developed in this study proved to be stable at 35 °C, indicating that it would adapt in the hottest regions of Brazil, mainly in the North, where arbovirus concentrations are higher. This study emphasized that it is possible to develop solutions that are not aggressive to the environment and to man, using natural materials, such as gelatin, and regional ones, such as essential oils.

The small variations found between each evaluation parameter are related to the natural degradation of the polymeric formulations, however they were not able to compromise the stability of the biocide. The effectiveness of the essential oil of the species *Piper callosum in natura* has been demonstrated, the future intention is to test the natural active encapsulated in polymeric nanoparticles against *Aedes aegypti* larvae. Thus, it was possible to develop a biocidal formulation from biodegradable polymers, which behaves well in hot climates in Brazil and has a minimum durability of 25 days, without being compromised by external factors.

V. ACKNOWLEDGMENTS

We would like to thank the Nanostructured Polymers Laboratory (NANOPOL), where the formulation was developed, to EMBRAPA in the person of PhD. Francisco Célio Maia Chaves for supplying the essential oil of *Piper callosum*, to the Amazon Research Institute (INPA), for conducting biological tests and FAPEAM for funding this research.

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RESEARCH ARTICLE OPEN ACCESS

ASSESSMENTS AND EXPERTISE OF THE PATHOLOGICAL MANIFESTATIONS OF A RESIDENTIAL COMPLEX LOCATED IN THE SQUARE 14 OF JANUARY NEIGHBORHOOD IN THE CITY OF MANAUS

José Basílio da Silva Filho[1], Robson Edgar Faria[2], Darlei dos Anjos Lavor[3], Antônio Estanislau Sanches[4] and David Barbosa de Alencar[5]

[1, 2] Blauro Cardoso de Mattos Higher Education Institute - FASERRA. Manaus–Amazonas, Brazil.
[3] Northern University Center - UNINORTE. Manaus–Amazonas, Brazil.
[4] State University of Amazonas - UEA. Manaus–Amazonas, Brazil.
[5] Institute of Technology and Education Galileo of the Amazon - ITEGAM. Manaus–Amazonas, Brazil.

[2]http://orcid.org/0000-0003-2163-2296, [4]http://orcid.org/0000-0003-1669-9090, [5]http://orcid.org/0000-0001-6705-6971

Email: basiliocss@gmail.com, robsonedfaria@yahoo.com.br, darleilavor27@gmail.com, novo.sanches@gmail.com, david002870@hotmail.com

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ABSTRACT

This article aims to analyze the causes of pathological manifestations in a residential complex. This in situ investigation investigated and identified the types of pathologies found in the concrete structure as well as cataloging the main manifestations in specific rooms of the complex's central residence. From this, an appropriate treatment was determined for each room, meeting the specifications of ABNT technical standards for the recovery and maintenance of the structure. The manifestations found were: cracks, cracks, repression, stains, shedding of the paint on the walls and ceiling, leaching, efflorescence, carbonation, corrosion and exposure of the armor. These manifestations appeared in a very short period of the useful life of the structure after the completion of the building, around 7 years, which revealed many errors in architectural design, materials without technological control and with inferior functionality and quality, among others.

I. INTRODUCTION

Since the beginning of human development, when man, in general, has ceased to be a nomad, he has been perfecting his construction techniques and passing his scientific knowledge from generation to generation, accumulating an extensive collection of development of new construction technologies and improving its finite structures, combining several materials that make the product more durable.

The fast-paced development of civil construction to meet a growing demand for buildings, whether they be work, industrial or housing, driven by the modernization of society itself, promoted a great scientific and technological leap [1]. A building is any type of installation whose final purpose is to provide shelter for the performance of the most varied functions of man [2]. The construction process of a building follows as follows: initial idea, prior planning, design, manufacture of materials for use on the construction site, execution of the building's component parts and use [3]. During such processes, failures or carelessness of the most varied types can occur, which end up generating addictions and constructive problems of the previously mentioned steps [2]. In developing countries, such as Brazil, socioeconomic conditions caused the works to reach ever higher execution speeds, resulting in weak controls on the materials used and services [4]. The deficient training of engineers and architects, the housing policies and inconsistent financing systems, have been causing the gradual decline in the quality of our constructions, to the point of finding buildings that, before being occupied, are already virtually condemned [4]. The housing issue in Brazil still represents a challenge for Brazilian politics. With decades without incentive programs in the segment, the country has accumulated a gigantic housing deficit among the poorest families, who sought alternatives with informal construction in peripheral areas and hills. The creation of the "*My home, my life*" program in 2009 tries to reverse this situation, built with years of inexistence of public policies in the housing sector [5]. The

assessment of this situation is perhaps the main objective of the pathology of buildings, considering that this is the moment that requires technical intervention, so that it is still possible to rehabilitate the structure, postponing its useful life. It can also be said that when it comes to building performance, that if at a certain point in the useful life of a certain element it shows an unsatisfactory performance, it does not mean that it is necessarily condemned [6]. Normally, pathological problems are related to the drop in performance of buildings, this fall is directly related to the damage and constructive vices that appear in the building over time [7]. The housing problem is related to the consideration of the following parameters: quantity, quality, cost and durability [8]. Quantity is related to the housing deficit; quality encompasses other concepts such as performance and builds ability, in addition to being directly related to cost and durability. When carrying out appropriate and periodic maintenance that is part of a broader management process, it accepts the guarantee of a longer useful life and satisfactory structural and functional performance, identifying, through periodic inspections, existing faults, diagnosing them and indicating recovery actions [9]. The maintenance of structures is considered as one of the processes that make up the construction of a building, as important as the execution of it, to contribute to the absence of pathologies [6]. The part of engineering that examines the symptoms, the mechanism, the origins and the causes of failures in civil construction is defined as pathology, that is, it is the study of all the components that form the diagnosis of the problem [10]. After the appearance of pathological manifestations in a building, the problem tends to worsen rapidly, resulting in other secondary problems [11]. Pathological problems are not restricted to structures considered old. Structures that are well designed and executed, and used correctly can also perform poorly. However, with the development of knowledge of destructive processes, equipment and techniques for observing structures and taking into account the great technological evolution; it became possible to accurately diagnose most pathological problems [12]. Pathology, according to the Aurelio dictionary, is the part of Medicine that studies diseases. Like patients in medicine, buildings can also present diseases, such as cracks, stains, breaks, corrosions, cracks, among others [13]. The causes of the occurrence of pathological phenomena can be the most diverse, from natural aging, accidents, irresponsibility of professionals and users who choose to use materials outside specifications or do not perform the correct maintenance of the structure, often for economic reasons, among others [6]. The study of pathologies in buildings is of great importance in the search for quality in construction processes and in improving the habitability and durability of buildings. In order to avoid the appearance of pathological manifestations, it is necessary to make a detailed study of the origins in order to better understand the phenomenon and assist in decisions to define conduct and action plans against problems [14]. It cannot lead to the emergence of all pathological problems due to the lack of maintenance or adequate conducts by users, the emergence of pathological problems is due to a combination of errors in all phases of building design, structure efficiency, methods constructive, of the aggressive conditions of the environment, but there is a part of the users' fault for the lack of maintenance to the building [15]. In order for existing pathological manifestations to be eliminated, it is essential to conduct a detailed study of their origins [14]. This study, in addition to providing a better understanding of the mechanism involved in the phenomenon, can assist in the diagnosis of the problems encountered. These pathological manifestations need to be identified and resolved. For this, it is necessary to use analysis methods developed from theoretical and practical knowledge, in order to use them in the treatment of problems presented through the collection of relevant information and data [2]. Still adds that the lack of maintenance and lack of knowledge on the part of users about aggressive elements and about the concrete structure, such as prolonged exposure to humidity, application of aggressive products to concrete and reinforcement, can generate serious problems for the structure compromising all the work done so far in the previous stages [16]. The pathological manifestations that stand out the most in concrete are efflorescence, cracks, excessive arrows, corrosion of the reinforcement, and stains in exposed concrete, defects in landfill and compaction and problems due to the segregation of components of the concrete [3]. It is also surprising that, in general, pathological manifestations appear in a very characteristic way and with a well-established statistically occurrence [3]. Even considering that many buildings have given real examples of great durability, under totally adverse conditions, it is worth remembering that they do not have an infinite useful life.

Therefore, this article sought to submerge two important themes for civil engineering: pathological manifestations and the assessment of their supposed causes. The expert evaluation was carried out in a residential complex with vertical housing located in the neighborhood of "*Square 14 of January*" in the south central zone of the capital of the state of *Amazonas*, *Manaus*. The investigation tends to visualize the causes of the pathological manifestations of the central house of the complex, showing the aggressive agents that favored the appearance of the pathological manifestations, thus diagnosing the problem and considering a preventive maintenance that minimizes more appearances of these pathologies.

II. METHODOLOGY

Moisture is the greatest enemy of construction and the health of its occupants of a concrete structure [17]. It is against this evil that not much care is taken in the works, due to lack of knowledge of the correct solutions or lack of sense of responsibility, adopted by the negligence of the personnel in charge of the execution. It also adds that the temperature variation causes a volumetric change in the concrete structures [18]. In large concrete elements, such as dams or foundation blocks, cracks may appear due to the effects of thermal gradients caused by the heat of hydration of the cement, which can cause tensile stresses [18].

In view of these aggravating factors that are periodically common in the northern region of Brazil, with the relative humidity content ranging from 80% to 98% on hot days, this study applies some methodologies studied according to the visit of the concrete structure (residence) from which it presents pathological manifestations due to numerous factors, such as: the overload of the structure, the lack of surface drainage of the residences which causes several factors in relation to the humidity of the place, such as stains, discovery of the painting, discovery of the plaster exposing the steel frames and etc. Some information from the residents of the selected location indicated that these demonstrations were due to the large undue drainage of rainwater. However, after the on-site inspection to assess these causes, it was observed that the structure is overloaded due to a new pavement recently built (around 7 years old), from which the structure began to show many cracks and over time. Months it

evolved into cracks or cracks, efflorescence and leaching, as well as the detachment of concrete from the steel frame (corrosion caused by carbonation). After these identifications, the possible causes of the manifestations found in that residence were analyzed. The studied residence is located on Avenue Tefé, "*Square 14 of January*" neighborhood, in the south central area of the Amazon capital - Manaus, in the basement 1. This residential has two upper floors and two basements. The entire survey study of the site had a period of 15 days in the rainy season (December to May) and another 15 days in the Amazonian summer period (June to November) for the evaluation of both the structure and the pathological manifestations already evident in the site. The study of the soil was not possible due to the location around the residence, which is paved with concrete. But due to the fact that it is a land near a stream (stream), it is concluded that in the vicinity of the land there is a humid material (soil) where it was observed in a vacant land, some 200m (meters) close to the complex, it was noted that the soil is superficially very dark with a lot of organic material, with a high vegetation and solid urban waste (MSW) piled up, possibly thrown by neighboring residents.

The main concern of the study of pathologies that occur in civil construction is the knowledge of the causes of the problems and how to avoid them [19]. Through some studies you can have an idea about its causes. For the treatment of pathologies effectively, it is necessary to identify the causes that generated the non-compliance. When specifying materials and components, the designer must know their durability, either to assess whether they will meet the minimum desired performance, or to compare overall costs, which include maintenance and operating costs, as well as the protection of service life [20]. [19] Affirms that without due attention to these factors, several problems can be generated, with, for example, the low quality of specific materials, the specification of incompatible materials, insufficient or mistaken detailing, unworkable constructive detailing, lack of standardization and dimensioning errors, compromised performance and the overall quality of the built environment.

III. MATERIALS AND METHODS

III.1 STAINS

Moisture in buildings is one of the most frequent and most difficult problems to be dealt with in the field of civil engineering. Not only due to the complexity of the phenomena involved, but also to the problems related to construction flaws, mainly waterproofing. This problem is often associated with others, which makes its treatment even more difficult [2].

The appearance of stains in reinforced concrete buildings is usually influenced by excess moisture or highly porous structures where the weather ends up infiltrating under them causing the structure to expand. Below, the causes of the types of humidity in a building are listed, according to [21]:

• Rain moisture - caused specifically by the action of rain;

• Construction moisture - caused due to the porosity of materials, such as: concrete, bricks, structural blocks, mortars, paints and etc.;

• Condensation humidity - caused by the high moisture content of the air combined with a cold surface or not;

• Capillarity humidity - resulting from the capillarity absorption of water existing in the soil by the foundations of the walls and floors up to the facades and floors;

• Accidental humidity - arising from failures in the distribution piping and / or water collection systems of the construction.

Figure 1, below, shows stains all over the kitchen wall as well as details the detachment of the painting from both the wall and the ceiling (slab). The kitchen is located under the service area of the residence on the first floor where there is no gutter or water drainage pipe as shown in Figure 2, below.

Figure 1: Stains and paint detachment on the kitchen wall of the residence under evaluation.
Source: Authors, (2020).

Figure 2: External area of the kitchen wall where the service area of the current residence is located.
Source: Authors, (2020).

III.2 REPRESSION

Repression is excess weight, the accommodation of the building, the weakness of the material or the terrain causes the piece to deform or sink [22]. All soils are subject to repression, greater or lesser, depending on the conditions of the soil and groundwater [23]. Repression is the main cause of cracks and cracks in buildings, especially when differential repression occurs, that is, part of the work lowers more than another, generating unforeseen structural efforts and may even lead the work to ruin [19].

III.3 FISSURES

Fissures can be caused by a multitude of pathological manifestations, below [2]; one of the main causes is listed.

• Cracks cause by misture;

• Cracks caused by chemical changes in construction materials.

Cracks, as they are also known to cracks, can start to appear immediately in the architectural design of the building, which is generally related to the designer's lack of knowledge about the properties of the materials used in the work. Incompatibility between architectural, structural and foundation projects usually leads to stresses exceeding the material's resistance limits, thus creating cracks [24].

Second [25] among the pathological problems that affect buildings, cracks are particularly careful because:

a) They serve as a warning for a possible dangerous state of the structure;

b) They may cause the performance of the work in use to be compromised (water tightness, durability, acoustic insulation, etc.);

c) Psychological constraint to users.

In Figure 3, below, it shows one of the many cracks in the bathroom of the residence caused by repression in the structure.

Figure 3: Crack in the bathroom wall caused by repression of the structure.
Source: Authors, (2020).

III.4 LEACHING AND EFLORESCENCE

In civil construction, efflorescence, popularly known as saltpeter, is usually the name given to salt residues, which after having been diluted with water and passed through the building material by the capillary effect are recrystallized from the surface of the walls, then the water becomes evaporates and reaches the surface. These soluble salts may already exist on the building site or in the building materials of the wall. As in civil construction many of the materials used are hygroscopic, that is, they have the ability to absorb moisture from the air, the pathological manifestations of efflorescence are a very common phenomenon in everyday life [3].

For the reaction to occur, the presence of cement, water and soluble sulfates is necessary. For this reason, the joint use of cement and plaster is dangerous. One of the main causes of efflorescence is, therefore, the soluble salts found in raw materials. Acid water or water with a high concentration of chlorides and sulphates, when it enters the capillary pores of the concrete, dissolves the calcium hydroxide from the cement paste, which can later react with the carbon dioxide in the air to form carbonate and calcium ($CaCO_3$). This salt when carried by the water and is deposited on the surface of the coating layer, forming a white stain or stalactites, giving an undesirable aesthetic to the construction [3].

In Figure 4, below, one of the leaching processes is shown, which in this case is the thick white stain forming a foam in the external pipe that comes from the floors above.

In Figure 5, below, it shows a case of efflorescence in a semi-open hole in the slab in the service area of the house in evidence. It is noted that the pathological manifestation covering the whole orifice with drool and whitish spots is quite aggravated. It is also observed that the drool has an orange tint showing that the metallic structure is exposed.

Figure 4: Leaching in the external piping of the service area.
Source: Authors, (2020).

Figure 5: Efflorescence and leaching in the semi-open hole in the service area slab.
Source: Authors, (2020).

III.5 CORROSION AND THE CARBONATATION PHENOMENON

It states that corrosion and deterioration can be associated with mechanical, physical, biological or chemical factors [26].

Carbonation is the chemical reaction of hydrated cement compounds with carbon dioxide in the air. This carbonation reaction in cementations composites is a widely studied topic, especially in concrete due to the effect of depassivating the reinforcement of reinforced concrete structures, which initiates the process of oxidation and corrosion of steel. In this context, carbonation is understood as a harmful process to structures [27]. The carbonation process occurs due to the reactions of CO_2, present in the air, with the alkaline hydroxides present in the material. This occurs especially with calcium hydroxide, in an aqueous medium, forming calcium carbonate and reducing the pH, initially around 13, to values close to 8 [28].

Carbonation is one of the main causes of corrosion or deterioration of a reinforced concrete structure, especially in countries like Brazil with the tropical climate and specifically in places where CO_2 emission interacts with the relative humidity content of the air, such as in the northern region from the country.

In Figure 6, below, it shows the corrosion process and the detachment of the concrete metal reinforcement caused, possibly by the carbonation effect, where a part of the structure was exposed, being vulnerable to pathological manifestations.

Figure 6: Corrosion caused by the effect of carbonation on the reinforced concrete structure.
Source: Authors, (2020).

IV. RESULTS AND DISCUSSIONS

Determining the causes of anomalies in residential buildings is a very complex and extremely difficult task. It is not always possible to identify a cause in a unique and clear way, given, for example, the wide variety of elements and materials that make up the building, the multiple functions that the various parts of a building play and the elements of construction that integrate it, the complexity of the environment that involves the building and the different types of activities of its users, and the simultaneous performance of the various causative agents [29]. It states that anomalies can present several symptoms, which can rarely have a single cause, but which can generally have several causes that occur simultaneously or in sequence with the accumulation of effects over time [30]. Therefore, the same cause can cause different pathologies and, on the other hand, different symptoms. There are no predefined rules or procedures for determining the causes of an anomaly. Each case is a case and should be analyzed as such.

The following sections present the pathological manifestations found at the research site and, according to some authors specified in the scope of this research, demonstrate what caused these manifestations in this residence.

IV.1 ON PATHOLOGICAL MANIFESTATIONS

The form of manifestation of this problem and the nature of the humidity [21]. It emphasizes that the accumulation of fungi in the covering layers, be it of the most varied types, generate colonies that feed on organic materials [31]. The ideal places for their proliferation are areas that have condensation moisture and that there is no running water. This type of pathology can be caused by several factors, including hydrothermal variation.

Despite the fact that the residence is well ventilated and the side walls diagnosed with pathological manifestations where the afternoon sun is intense, the water that comes from the upper floor would have to be drained with an external pipe that went to the sewers in order to stop the constant flow of water. Water on these walls and thus not seeping into the soil causing a possible expansion in the reinforced concrete structure, even if it is thermal as well as functional.

The waterproofing of these structures is also a viable alternative both in the appearance of new manifestations and in the interruption of the aggravation of the manifestations that are in the place.

In order to avoid corrosion due to carbonation within the service life, concrete structures are required to have a concrete covering with sufficient thickness and resistance against carbonation [32].

Temperature plays a dual role in deterioration processes. If on the one hand it causes an increase in the rate of corrosion and ion mobility, on the other hand the decrease can give rise to condensation, creating local increases in the moisture content [33].

The detachments are characterized by the loss of adhesion of the substrate's ceramic plates, or of the adhesive mortar, when the stresses arising in the ceramic coating exceed the adhesion capacity of the connections between the ceramic plate and the adhesive mortar and/or plaster [34].

V. CONCLUSION

It is important to know the micro climate in which the building is located [35]. Due to the way and the intensity that the rain acts on each of the facades, they must be designed differently, the most affected by the action of rain with greater tightness.

In this case, the lack of maintenance and the lack of drainage in the residential complex are the main causes of pathological manifestations, which can lead to a collapse very soon. Given the facts studied, it is concluded that:

a) All the results obtained in this study were very successful as well as tireless research to obtain all the assessments of the causes of pathological manifestations on the spot;

b) The site under study is in urgent need of maintenance and meticulous attention so that it does not affect the other residences of the complex causing a tragedy;

c) The cracks and cracks found in the residence under study were caused due to the settlement where the structure sank due to excess weight in the soil where it is notable that the foundations chosen at the time of construction are not suitable for this complex;

d) The waterproofing of the affected areas will stop the growth and the appearance of new pathological manifestations in the structure of the complex;

e) For the exposed areas of the reinforcement of the reinforced concrete structure, it is suggested that they be treated and covered with the appropriate ABNT specifications.

Therefore, the expert assessment was meticulously investigated.

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RESEARCH ARTICLE OPEN ACCESS

ROBUST COORDINATED DESIGN OF AVR+PSS USING QUANTUM PARTICLE SWARM OPTIMIZATION

Raimundo Nonato Diniz Costa Filho[1] and Vicente Leonardo Paucar[2]

[1] Federal University of Maranhão - UFMA. Balsas–Maranhão, Brazil.
[2] Federal University of Maranhão - UFMA. São Luís–Maranhão, Brazil.

[1]http://orcid.org/0000-0001-8926-2071, [2]http://orcid.org/0000-0002-7950-7693

Email: raimundo.diniz@ieee.org, lpaucar@ieee.org

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ABSTRACT

Automatic Voltage Regulator (AVR) regulates the generator terminal voltage by controlling the amount of current supplied to the generator field winding by the exciter. Power system stabilizer (PSS) is installed with AVR to damp the low frequency oscillation in Electric power system (EPS). However, for years, PSS paired with high initial response AVR have served as an effective means of meeting sometimes conflicting system stability requirements. In this context, this work presented a methodology with the objective of tuning the parameters of AVR and PSS to improve all the rotor angular stability of an EPS. The tuning of RAT and ESP was modeled using a multi-objective problem. Applying the ε-constraint method and a PSO, based on the quantum behavior of the particles, called QPSO, it was possible to solve the problem presented. The AVR and PSS were tuned optimally in a 5-machine equivalent of the South/Southeast Brazilian system. The proposed methodology was compared with the specialized literature and presented better results both for stability to small disturbances and for transient stability.

I. INTRODUCTION

Rotor angular stability (electromechanical stability) refers to the ability of synchronous machines in the network to maintain synchronism under large (transient stability) or small (small-signal stability) disturbances and which may be directly associated with maintaining or restoring the balance between torque electromagnetic and the mechanical torque of each of the system's synchronous machines [1,2]. The study of electromechanical stability in Electrical Power Systems (EPS) is essential, since this problem can cause serious technical and economic problems for EPS [3,4].

The AVR (Automatic Voltage Regulator) and PSS (Power System Stabilizers), when properly tuned, are one of the most economical ways to improve electromechanical stability. In general, for these controllers to contribute positively to the electromechanical stability, the tuning of the AVR and PSS follows the following sequence: first step is to design the AVR and then, in a second step, adjust the parameters of the PSS [5].

The adjustment of the AVR and PSS parameters aims to satisfy transient stability performance and improve the damping of low frequency electromechanical oscillations [6]. However, the current AVRs have high gains that can affect and shift the oscillation modes to an unstable (or poorly stable) region, on the other hand, PSS can contribute, in a negative way, to the transient stability [7-9]. Thus, a coordinated design of these controllers is important, since the parameters obtained in the tuning of PSS, in order to improve the damping of the system, are not always adequate in the analysis of transient stability.

The tuning of these controllers is carried out separately using control techniques, such as [8,9] frequency response and [10,11] applies the idea of centralized control. With the advent of Artificial Intelligence (AI) techniques it was possible to apply them to solve the problem presented. The main techniques applied were genetic algorithms [7] and particle swarm optimization (PSO - Particle Swarm Optimization) [6].

The objective of the article is to apply a PSO, based on the quantum behavior of the particles, called QPSO (Quantum PSO)

[12], for tuning the parameters of AVR and PSS, in order to improve all electromechanical stability. The main features of QPSO are its fewer parameters to adjust, easy implementation and quality of solution. The effectiveness of the proposed approach has been demonstrated through computer simulation in a 5-machine equivalent of the South/Southeast Brazilian system.

II. APPLIED METHODOLOGY

II.1 AVR AND PSS MODELS

AVR regulates the generator terminal voltage by controlling the amount of current supplied to the generator field winding by the exciter. The AVR model, adopted in the simulations of this work, consists of the gain K_A and the time constant T_A of the regulator. The control device most used for the damping of electromechanical oscillations is the PSS. The basic function of a PSS is to add damping to the generator rotor oscillations by controlling its excitation using auxiliary stabilizing signal(s) [1]. The PSS consists of three blocks: a gain block (K_{pss}), a washout signal block (T_w) and phase compensation blocks (T_1-T_4). As a feedback signal for the PSS, variations in the angular velocity ($\Delta\omega$) of the PSS installation machines were used. The structures of these controllers are illustrated in Figure 1.

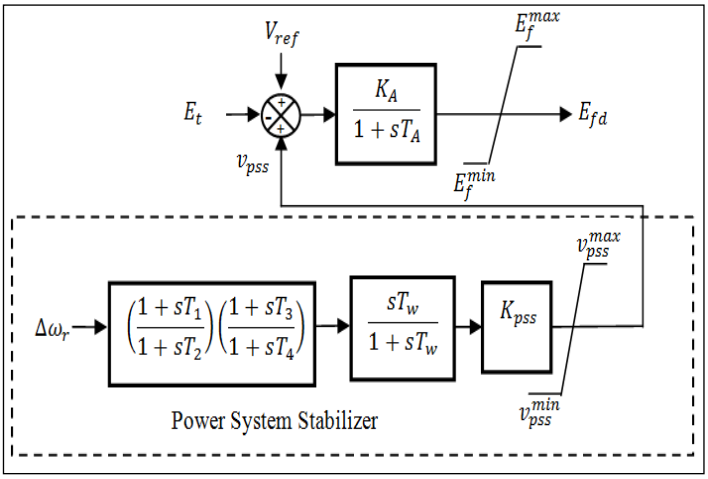

Figure 1: AVR and PSS models.
Source: Authors, (2020).

II.2 SMALL - SIGNAL STABILITY INDEX

The goal is to improve all electromechanical stability. This type of stability includes the analysis of stability to small disturbances and transient. The objective function used is based on indexes. These indexes are obtained through the analysis of stability to small disturbances and transient.

The analysis of stability to small disturbances involves the linearization of equations (1) around an operating point (x_0, r_0) obtained by a power flow program [1]:

$$\begin{bmatrix}\dot{\Delta x}\\ 0\end{bmatrix} = \begin{bmatrix}J_1 & J_2\\ J_3 & J_4\end{bmatrix}\begin{bmatrix}\Delta x\\ \Delta r\end{bmatrix} \quad (1)$$

Assuming that the Jacobian matrix J_4 is non-singular, the state matrix of the system can be obtained by eliminating the vector of the algebraic variables Δr:

$$\dot{\Delta x} = (J_1 - J_2 J_4^{-1} J_3)\Delta x = \boldsymbol{A}\Delta x \quad (2)$$

Where the symbol **A** represents the system state matrix.

The small disturbance stability assessment is based on the analysis of the eigenvalues of the system state matrix. The eigenvalues can be real or conjugated complex:

$$\lambda = \sigma \pm j\omega \quad (3)$$

The real part σ is related to the exponential growth of the response. The imaginary part, on the other hand, determines the oscillation frequency of the respective oscillation mode. The frequency of the oscillation mode in Hz is given by (4). The damping ratio for this frequency is given by (5).

$$f = \frac{\omega}{2\pi} \quad (4)$$

$$\zeta = \frac{-\sigma}{\sqrt{\sigma^2 + \omega^2}} \quad (5)$$

II.3 TRANSIENT STABILITY INDEX

The study of transient stability involves the representation of the EPS considering its nonlinearities. It is convenient to describe the behavior of the system with the angles of the generators expressed in relation to the center of inertia of all generators. The position of the Center of Inertia (COI) can be represented by a linear combination of the angles of all generators as follows in expression (6):

$$\delta_{COI} = \frac{1}{H_T}\sum_{i=1}^{N_g} H_i \times \delta_i \quad (6)$$

Where H_T is the sum of the inertia constants of all N_g generators in the system.

The accelerating power P_{ai} of generator i with respect to COI can be expressed by:

$$P_{ai} = P_{mi} - P_{ei} - \frac{H_i}{H_T}P_{COI}$$
$$P_{COI} = \sum_{i=1}^{N_g}(P_{mi} - P_{ei}) \quad (7)$$

Where P_{mi} and P_{ei} are the mechanical and electrical powers of generator i, respectively.

$$F = \begin{bmatrix} P_{a1} = P_{m1} - P_{e1} - \frac{H_1}{H_T}P_{COI} \\ P_{a2} = P_{m2} - P_{e2} - \frac{H_2}{H_T}P_{COI} \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \\ P_{aNg} = P_{mNg} - P_{eNg} - \frac{H_{ng}}{H_T}P_{COI} \end{bmatrix} \quad (8)$$

$$\Theta = \begin{bmatrix} \theta_1 = \delta_1 - \delta_{COI} \\ \theta_2 = \delta_2 - \delta_{COI} \\ \dots\dots\dots\dots\dots\dots\dots \\ \theta_{Ng} = \delta_{Ng} - \delta_{COI} \end{bmatrix}$$

The vector of the rotor angles and the accelerating power of the generators in relation to the COI are relevant measures that can be used to detect the instability of the system in the time domain [13]. It is possible to define the vectors *F* (formed by the accelerating powers of the synchronous generators in relation to the COI) and Θ (formed by the angles of the synchronous generators in relation to the COI) to develop the index used in the evaluation of the transient stability [13]. In this way, the stability of the system can be determined by using the internal product (9).

$$Dot = F * \Theta^t = F_1 * \Theta_1 + \cdots + F_{Ng} * \Theta_{Ng} \qquad (9)$$

II.4 COORDINATED TUNING OF AVR AND PSS

The ε-constraint method was introduced by Haimes for problems involving two objective functions [14]. In this method, one of the objectives is chosen as the only objective to be optimized, while the others are incorporated into the set of restrictions of the problem. Mathematically, the ε-constraint method can be written as follows, if the function to be minimized is $f_2(x)$, then the other objective functions are treated as problem inequality constraints, that is [15,16]:

$$\min f_2(x)$$
$$subject\ to\ f_i(x) \leq \varepsilon_i, i = 1, \cdots, p, i \neq 2, x \in X \qquad (10)$$

Where $\varepsilon = (\varepsilon_1, \cdots, \varepsilon_p) \in R^p$ and is defined by the user.

This method is the most appropriate to be used for the AVR and PSS tuning problem in order to improve the angular stability, since in this multi-objective problem there are two purposes considered: to improve the stability to small disturbances and the transient stability. However, in practical applications, when analyzing stability to small disturbances, a minimum damping level is required for all electromechanical oscillation modes (e.g, ζ_o = 5%) [17], so in this case it can be considered as objective function an index which expresses, in numerical values, the situation of the system after a major disturbance has occurred (such as short circuit) and the other objective function, in the case of stability to small disturbances, will be incorporated into the set of problem constraints, as shown in Figure 2.

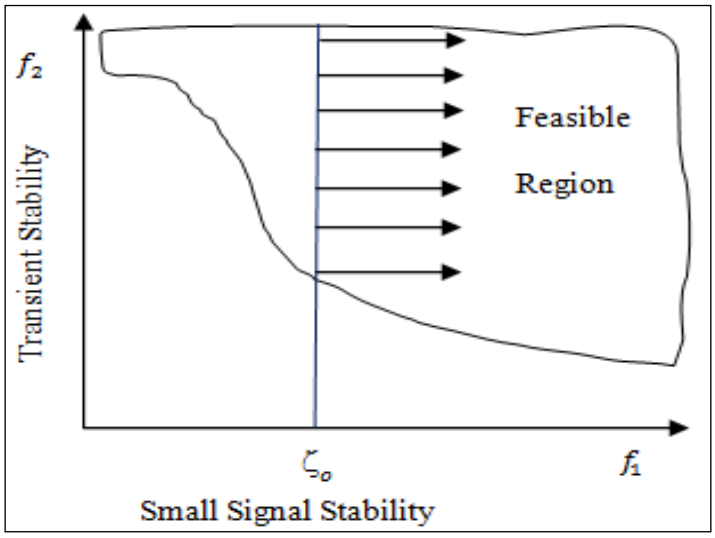

Figure 2: AVR and PSS models.
Source: Authors, (2020).

The index to represent stability to small-signal stability is given by the objective function f_1. Where, *NP* is the number of operation points considered in the analysis of small-signal stability and ζ_{NPmin} is the smallest damping ratio of the closed-loop system at the *NP* operation point.

$$\mathrm{f_1} = \min(\zeta_{\mathrm{1min}}, \zeta_{\mathrm{2min}}, \cdots, \zeta_{\mathrm{NPmin}}) \qquad (11)$$

The objective function f_2 refers to the problem of transient stability.

$$f_2 = \int_0^{t_{sim}} Dot \times dt \qquad (12)$$

The problem can be formulated mathematically according to equation (13):

minimize f_2
Subject to

$$\begin{gathered} \mathrm{f_1} \geq \zeta_{\mathrm{o}} \\ K_{A_{min}} \leq K_A \leq K_{A_{max}} \\ T_{A_{min}} \leq T_A \leq T_{A_{max}} \\ K_{pss_{min}} \leq K_{pss} \leq K_{pss_{max}} \\ T_{i_{min}} \leq T_i \leq T_{i_{max}}, \qquad i = 1, \cdots, 4 \end{gathered} \qquad (13)$$

Where ζ_{o} is the minimum damping considered when tuning the AVR and PSS at all points of operation.

III. QPSO ALGORITHM

III.1 PSO

PSO is a global optimization method developed by Kennedy and Eberhart [18]. It was developed from collective intelligence and is based on research on the behavior of bird flock and fish schools. The first step of the algorithm is to generate the *N* particles that will form the swarm with their respective positions. Each particle is initialized with a position and speed at random. The algorithm updates the velocity and position vectors until the maximum number of iterations is reached. To update the velocity vector of each particle, the expression (14) is used. To update the position vector of each particle, equation (15) [19] is used.

$$V_{ij}^{t+1} = w * V_{ij}^t + C_1 * r_1 * \left(P_{best_{ij}}^t - X_{ij}^t\right) + C_2 * r_2 * \left(G_{best_j}^t - X_{ij}^t\right) \qquad (14)$$

$$X_{ij}^{t+1} = X_{ij}^t + V_{ij}^{t+1} \qquad (15)$$

Where $i = 1,2, \ldots, N$, and N is population size; $j = 1,2, \ldots, dim$, and dim is the dimension of the problem; V_{ij}^{t+1} is the current particle speed; X_{ij}^t is the current position of the particle; $P_{best_{ij}}^t$ is the best position found by the particle ij; $G_{best_j}^t$ is the best position found among all particles i; t is the number of iterations; w is the inertia weight; C_1 and C_2 are generally acceleration coefficients; r_1 and r_2 are random numbers uniformly distributed in the interval [0,1]; X_{ij}^{t+1} is the position of each particle i-j in the iteration $t+1$; V_{ij}^{t+1} is the velocity vector of particle i-j in the iteration $t+1$.

III.2 QPSO

The QPSO algorithm is based on the quantum behavior of particle movements, so it is a type of algorithm with probabilistic characteristics, since the state of a particle is represented by the wave function ψ(x, t), instead of the position and speed as in the conventional model (PSO).

Based on the trajectory analysis, the reference [20] demonstrated that, to guarantee the convergence of the PSO, each particle must converge to its local attractor p_{ij}^t, whose coordinates are:

$$p_{ij}^t = \varphi_{ij} \times P_{best_{ij}}^t + (1 - \varphi_{ij}) \times G_{best_j}^t \quad (16)$$

Where φ_{ij} is a random number uniformly distributed over (0.1).

In the QPSO algorithm, the dynamic behavior of each particle is widely divergent compared to the classic PSO, and the exact position and velocity values cannot be determined simultaneously. In this scenario, it is only possible to find the particle at position X_{ij}, at time t, using the probability density function $|\psi(x,t)|^2$, which depends on the potential field in which the particle is located [12]. Using the Monte Carlo method, one can obtain the *jth* component of the position of particle *i* in the iteration $(t + 1)$ through the expression (17) [12,20].

$$\begin{cases} X_{ij}^{t+1} = p_{ij}^t + \alpha \times |C_j^t - X_{ij}^t| \times \ln\left(\frac{1}{u_{ij}^{t+1}}\right), if\ rand \geq 0.5 \\ X_{ij}^{t+1} = p_{ij}^t - \alpha \times |C_j^t - X_{ij}^t| \times \ln\left(\frac{1}{u_{ij}^{t+1}}\right), if\ rand < 0.5 \end{cases} \quad (17)$$

Where uij is a random number uniformly distributed over (0.1) and C_j is the best average position, which can be calculated by averaging the best individual positions of all particles.

$$C_j^t = \frac{\sum_{i=1}^{N} P_{best_{ij}}^t}{N}, (1 \leq j \leq dim) \quad (18)$$

The expansion and contraction coefficient α (sometimes represented by β [20]) controls the convergence speed of the algorithm during the search process. Behavior in the literature is suggested in a linearly decreasing manner and obeys equation (19) [12].

$$\alpha^t = \alpha_0 + (\alpha_1 - \alpha_0) \times \frac{(t_{max} - t)}{t_{max}} \quad (19)$$

Where t_{max} is the maximum number of iterations, α_1 and α_0 are the final and initial values of the parameter α and t is the current iteration.

IV. RESULTS

The purpose of this section is to show the results obtained by applying the proposed methodology to an equivalent system in South-Southeast Brazil. All state matrices were obtained using the PacDyn software [21]. The values of angles and accelerating power, in the analysis of transient stability, were obtained using the ANATEM [22]. Several functions have been written in MATLab (Matrix Laboraty) language to allow communication between the programs PacDyn and ANATEM. The limits of the PSS parameters are: 0.01≤Kpss≤ 50; 0.001≤ (T1, T2, T3, T4) ≤ 2. The value of the constant T_w was 3 seconds. The limits of the AVR parameters are 20≤KA≤400 and 0.01≤TA≤0.2. In the analysis of transient stability, it is important to consider the output limits of the AVR and PSS [1], the limits considered in all simulations were ± 10p.u and ± 0.25p.u for the AVR and PSS, respectively [8]. The QPSO parameters [12] adopted in the simulations are: population size = 50; maximum number of iterations = 60, $\alpha_1 = 1$ and $\alpha_0 = 0.5$.

IV.1 TEST SYSTEM

This system is a seven-bus, five-machine equivalent model of the Southern/Southeastern Brazil system. The synchronous generators were represented by a fifth-order model. The order of the open loop system is 29x29. For the application of the methodology, there are five different operation points or cases, taken from [23] and shown in Table 1. It is observed that the lowest damping value occurs at operation point 5 with -16.58% and frequency oscillation of 0.796 Hz. Through the analysis of the residues, 2 PSS was installed in the system, a PSS in the Segredo generator (bus 3) and the other PSS in the Itaipu generator (bus 4).

The large disturbance considered in the project was an application of a three-phase short circuit on bus 5 with duration of 115 ms followed by the opening of line 5-1. The simulation time (t_{sim}) considered was 5 seconds and the damping required for all operating points was $\zeta_0 = 10\%$.

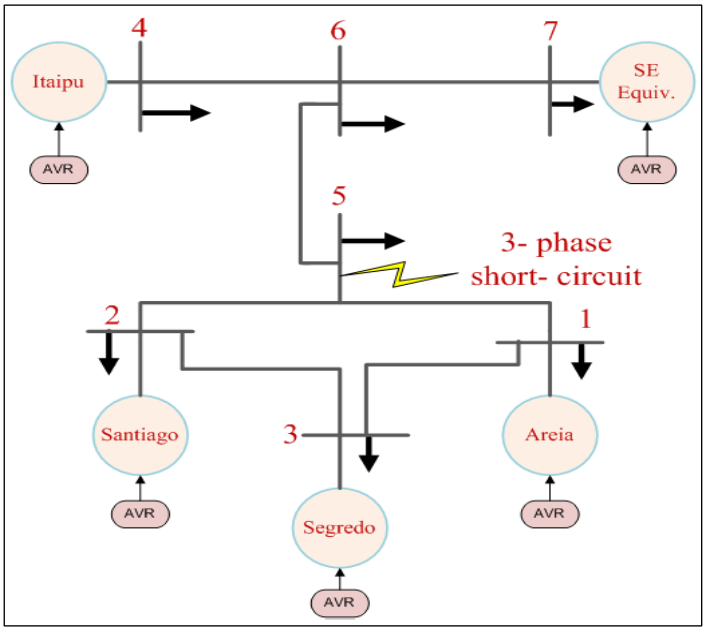

Figure 3: Equivalent Brazilian system configuration.
Source: Authors, (2020).

Table 1: Operating conditions.

Case #	X_{5-6}	X_{6-7}	Mode 1		Mode 2	
	pu	pu	f(Hz)	ζ(%)	f(Hz)	ζ(%)
1	0,39	0,57	0,858	-11,90	0,935	3,83
2	0,50	0,57	0,855	-12,10	0,918	3,50
3	0,80	0,57	0,851	-12,66	0,877	2,77
4	0,39	0,63	0,830	-14,04	0,931	4,04
5	0,39	0,70	0,796	-16,58	0,926	4,18

Source: Authors, (2020).

After applying the QPSO algorithm, the PSS and AVR parameters were obtained, which are presented in Table II. The

map of closed-loop poles is illustrated in Figure 8. It is observed that, for all operating points, closed-loop poles have damping above the required (ζ_0 = 10%) in the project (case 1- ζ_{min} = 13.95%; case 2- ζ_{min} = 13.90%; case 3- ζ_{min} = 13.79%; case 4- ζ_{min} = 13.95% and case 5- ζ_{min} = 13.96%). The closed-loop pole map considering the 5 operating conditions is shown in Figure 4. Through the application of the presented methodology, it was possible to stabilize the system with respect to transitory stability and, at the same time, improve the damping levels of all the considered operation points.

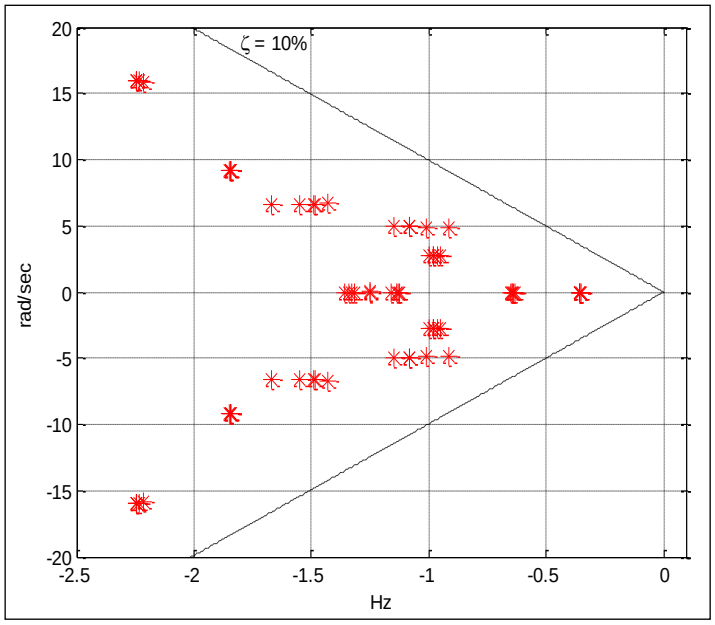

Figure 4: Closed-loop pole map.
Source: Authors, (2020).

Table 2: Optimal control parameters.

	K_A		T_A		
AVR_3	74.5110		0.2000		
AVR_4	157.9200		0.0705		
	K_{pss}	T_1	T_2	T_3	T_4
PSS_3	45.618	0.0612	0.0010	0.2552	0.0010
PSS_4	31.295	0.6882	0.0010	0.2667	0.0013

Source: Authors, (2020).

IV.2 UNCOORDINATED DESIGN OF AVR+PSS

Originally, the AVR of generators 3 and 4 have values of K_A and T_A equal to 30 p.u and 0.05 s, respectively. The transfer functions of the PSSs obtained through the classic design have been removed from reference [23] (named in design article C). The minimum damping values obtained through the use of PSSs in Segredo and Itaipu are: case 1- ζ_{min} = 9.54%; case 2- ζ_{min} = 9.66%; case 3- ζ_{min} = 8.81%; case 4- ζ_{min} = 9.03% and case 5- ζ_{min} = 7.17%.

For comparison, a three-phase short circuit was applied to bus 5 in 0.200 seconds and removed in 0.312 seconds followed by the opening of line 5-1. Figures 5 and 6 show the behavior of the angle (with respect to generator 7) and the voltages of all the generation buses with the PSS of generators 3 and 4 designed by the classic control, respectively. In contrast, Figures 7 and 8 show the behavior of the angle (with respect to generator 7) and the voltages of all the generation buses with the PSS and AVR of generators 3 and 4 tuned by the QPSO algorithm, respectively. Note that the response of the angles of the generators and voltage of the generation buses obtained by applying the proposed methodology is better than that obtained by the classical control theory.

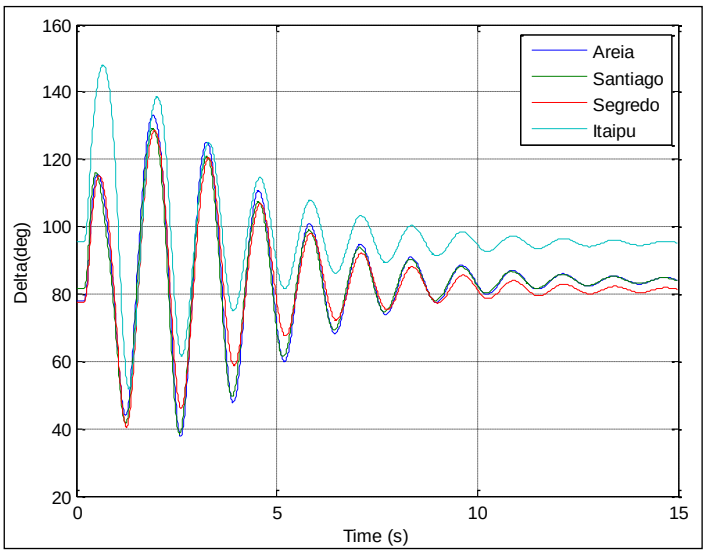

Figure 5: Generators rotor angle - classic design.
Source: Authors, (2020).

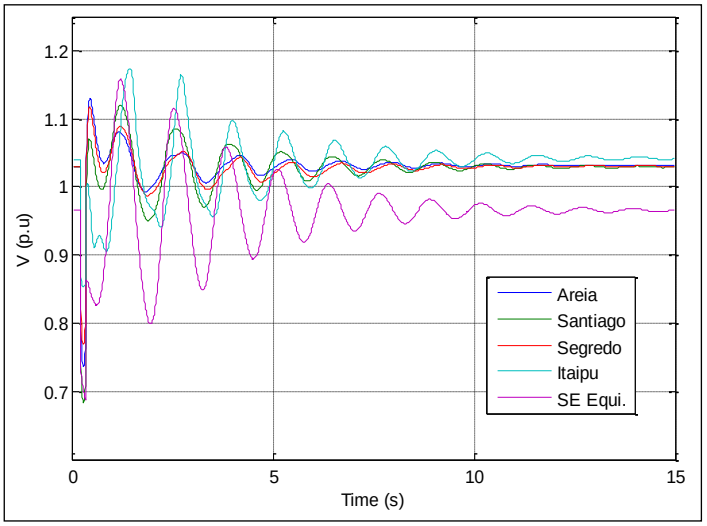

Figure 6: Generation bus voltage - classic design.
Source: Authors, (2020).

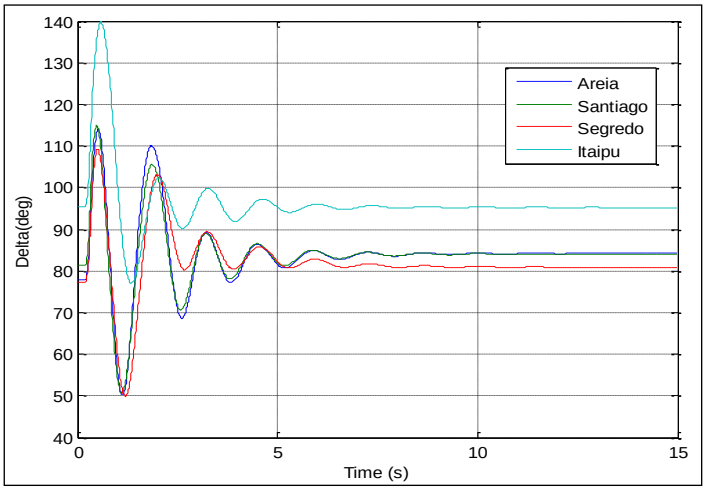

Figure 7: Generators rotor angle - QPSO.
Source: Authors, (2020).

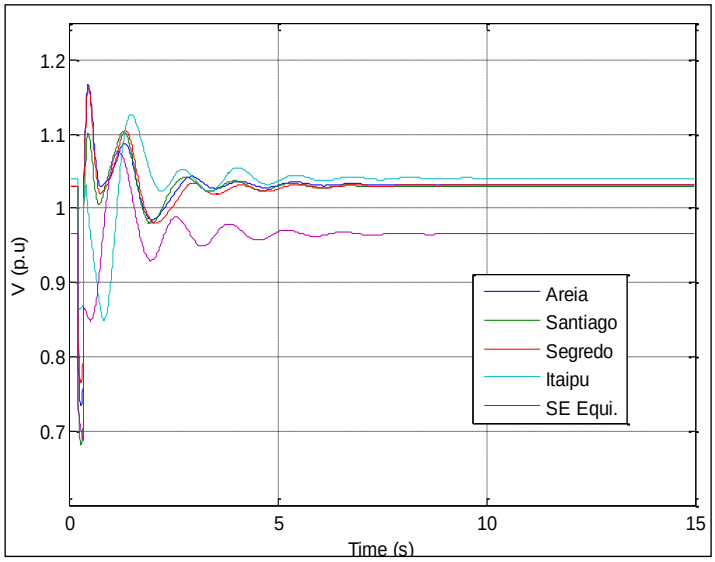

Figure 8: Generation bus voltage - QPSO.
Source: Authors, (2020).

V. CONCLUSIONS

This paper presented a methodology with the objective of tuning the parameters of AVR and PSS to improve all the electromechanical stability of an Electric Power System (EPS). The tuning of AVR and PSS was modeled using a multi-objective problem. Applying the ε-constraint method and a PSO, based on the quantum behavior of the particles, called QPSO, it was possible to solve the problem presented. The AVR and PSS were tuned optimally in a 5-machine equivalent of the South/Southeast Brazilian system. The proposed methodology was compared with the specialized literature and presented better results both for stability to small disturbances and for transient stability.

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RESEARCH ARTICLE OPEN ACCESS

ADSORPTION KINETICS OF PHENOL FROM AQUEOUS SOLUTION USING SUGARCANE BAGASSE ASH AS LOW-COST ADSORBENT MATERIAL

Yan Miguel Gallo[1], Francisca Mónica Calero de Hoces[2], Iván Leandro Rodríguez Rico[3], María Ángeles Martín Lara[4] and Julio Omar Prieto García[5]

[1] Cienfuegos Center for Environmental Studies. Cienfuegos, Cuba.
[2, 4] Department of Chemical Engineering, Faculty of Sciences, University of Granada. Granada, Spain.
[3, 5] Faculty of Chemistry-Pharmacy, Central University "Marta Abreu" of Las Villas. Santa Clara, Cuba.

[1]http://orcid.org/0000-0001-8198-3608, [2]http://orcid.org/0000-0001-8029-8211, [3]http://orcid.org/0000-0003-1295-5368, [4]http://orcid.org/0000-0001-9515-7307, [5]http://orcid.org/0000-0002-9279-4412

Email: yan@ceac.cu, mcaleroh@ugr.es, ivanl@uclv.edu.cu, marianml@ugr.es, omarpg@uclv.edu.cu

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ABSTRACT

The sugarcane bagasse fly ash was used to evaluate its adsorption behavior for phenol removal from aqueous solution at three different temperatures. Adsorption tests were performed in batch reactors and also in fixed-bed columns. Pseudo-first order, pseudo-second order and intraparticle diffusion kinetic models were applied to describe adsorption kinetics in batch systems. The pseudo-second model fitted appropriately the obtained experimental data at the three different temperatures tested. Thomas, Yoon-Nelson, Adams-Bohart and Dose-Response mathematical models were tested for describing phenol adsorption in dynamic systems (fixed bed columns). Experimental data were well-fitted to the non-linear form of all these models with high regression coefficients.

I. INTRODUCTION

Phenols are organic compounds produced and used in different industry such as coke, oil refineries, pharmaceutical and phenolic resin plants [1]. Phenols are widely used and, consequently, they are frequently detected in water. They are some of the most dangerous pollutants and pose an important threat to both environment and human health, even at low concentrations [2-4]. The discharge of phenolic waste into watercourses affects to the flora and fauna and the ingestion of small amounts beings may cause affections human health [5]. For all these reasons, phenols are pollutants classified as pollutants of high priority. Consequently, their treatment is very important for safe discharge to the environment. Various methods have been used to remove phenol from aqueous solutions including adsorption, ion exchange, oxidation, precipitation and solvent extraction [6]. Especially adsorption is an interesting technique since it has low cost and is greatly efficient [7], in wastewater treatment. In addition, the cost of operation of the adsorption procedure can be significantly decreased with the use of solid waste adsorbents.

Sugarcane bagasse is a solid waste produced as a consequence of sugar production in industries. The high amounts of sugarcane bagasse generated after the extraction of sucrose from sugarcane has to be treatment and safely disposal. Sugarcane bagasse has been reported as suitable adsorbent material for wastewater treatment and particularly for metal cations removal from wastewaters [8-10]. For example, recently, [10] prepared an activated carbon from sugarcane bagasse and investigated kinetics and mechanisms of Cr(VI) adsorption onto the carbonaceous material.

Sugarcane bagasse is frequently used as fuel in combustion systems generating new solid waste, mainly two types of ashes: the sugarcane bagasse bottom ashes (SBBA) and the sugarcane bagasse fly ashes (SBFA). Some researchers have analyzed the use of SBFA in civil engineering [11-14]. However, finding other recycling processes to give value to this waste is of great interest. Researchers as [15] performed a complete characterization of sugarcane bagasse ash for its use as adsorbent material. Now, in the present study, the application of SBFA as adsorbent material for the removal of phenol from wastewater was studied. Previously, [16] already used SBFA as adsorbent for

the removal of phenol from aqueous solution. The previous study showed that the SBFA was an effective adsorbent for the removal of phenol from aqueous solution. However, in the work of [16] only adsorption tests in batch systems were carried out.

In this work, the sorption kinetics of phenol in aqueous solution, in batch and column systems, using SBFA was investigated. Authors consider that the study of kinetics in adsorption processes is important since it clarifies the mechanism of adsorption.

II. DEVELOPMENT

II.1 MATERIAL

Sugarcane bagasse fly ash was collected from the particulate collection devices attached to the boiler furnaces in a Sugar Factory from Villa Clara, Cuba. Then, the ash was sieved using a 1 mm sieve, dried at 110 °C for 6h and stored in vacuum desiccator, without any pretreatment, for further analyses. A complete characterization of SBFA was performed in a previous work [15] and a summary of the main composition and physical properties was reported in Table 1.

Table 1: Chemical and physical properties of SBFA.

Chemical properties									**Physical properties**		
Si (%)	**Al (%)**	**Fe (%)**	**Ca (%)**	**Mg (%)**	**K (%)**	**Organic matter (%)**	**Inorganic matter (%)**	**pH_{pzc}**	**Bulk density (g/cm^3)**	**Real density (g/cm^3)**	**Surface area (m^2/g)**
29.54	0.36	0.60	7.01	1.14	5.81	18.02	81.98	7.40	0.53	2.26	79.11

Source: Adapted from [15].

II.2 BATCH ADSORPTION EXPERIMENTS

The pH of the aqueous solution of phenol was 7.0, this value has been used in other studies [17] and the work temperatures were 27; 40 and 60 °C. For each experimental test, 50 mL of aqueous solution with a phenol concentration of 50 mg/L was taken in a 250 mL flask containing 5g of adsorbent; the solution was stirred at a constant shaking rate for 50 minutes and the supernatant liquid was collected at different contact times and analyzed for the residual concentration of phenol using the method ASTM Designation: D 1783 – 01 Standard Test Methods for Phenolic Compounds in Water [18], using a spectrophotometer GENESYS 10S UV-VIS, Thermo Scientific.

Pseudo-first-order, pseudo-second-order and intraparticle diffusion models, were used for analyzing characteristic kinetic parameters of phenol adsorption onto SBFA. A summary of the equations of the models is presented in Table 2.

Table 2: Summary of the equations of the kinetic models applied in this work for describing phenol adsorption onto SBFA in a batch system.

	Pseudo-first-order model	**Pseudo-second-order model**	**Intraparticle diffusion model**
Equation	$\frac{dq_t}{dt} = k_1(q_e - q_t)$	$\frac{dq_t}{dt} = k_2(q_e - q_t)^2$	$q_t = k_{(id)} t^{1/2} + C$
	$\mathrm{Ln}\left(\frac{q_e - q_t}{q_e}\right) = -k_1 t$	$\frac{t}{q_t} = \frac{1}{k_2 \cdot q_e^2} + \frac{t}{q_e}$	
Parameters	where q_e and q_t are the amounts of adsorbate uptake per mass of adsorbent, mg/g, at equilibrium and at any time t (min), respectively, and $k_1(min^{-1})$ is the rate constant of the pseudo-first order equation.	where k_2 is the pseudo-second-order rate constant, g/(mg·min).	where, $k_{(id)}$ is the intra-particle diffusion rate constant ($mg/g \cdot min^{1/2}$) and C (mg/g) is a constant that gives idea about the thickness of the boundary layer.
Reference	[19]	[20-21]	[22]

Source: [19-22].

II.3 COLUMN ADSORPTION EXPERIMENTS

Column adsorption studies were developed in a glass column having an internal diameter of 2.3 cm and 44 cm height at 27 ºC. Experiments were carry out, changing the absorbent mass (47.5 y 65.0 g), from these masses was obtained a bed height of 25.0 and 32.5 cm, respectively.

Inlet phenol concentration was 5.0 mg/L and the flow rate was 0.012 L/min. The phenol samples were collected every 10 min and were prepared for concentration determination analyses by spectrophotometry.

Different column kinetic models were used in this study to describe the dynamic behavior of adsorption in the fixed-bed column. A summary of the equations of the models is presented in Table 3.

Table 3: Summary of the equations of the kinetic models applied in this work for describing phenol adsorption onto SBFA in a fixed-bed column.

Equation	Parameters	Reference
$\frac{C}{C_0} = e^{K_{AB}C_0 t - \frac{K_{AB}N_0 Z}{v}}$	K_{AB}: kinetic constant, $L \cdot mg^{-1} \cdot min^{-1}$ N_0: volumetric adsorption capacity, $mg \cdot L^{-1}$ v: linear flow rate, $cm \cdot min^{-1}$ Z: height in the column, cm	Bohart and Adams [23]
$\frac{C}{C_0} = \frac{1}{1 + \exp\left(\frac{K_{Th}}{Q}(q_0\, m - C_0\, V_{eff})\right)}$	K_{Th}: rate constant, $mL\ min^{-1}\ mg^{-1}$ q_0: maximum concentration of solute in the solid phase, $mg \cdot g^{-1}$	Thomas [24]
$\frac{C}{C_0} = \frac{1}{1+\exp(K_{YN}(\tau - t))}$	K_{YN}: rate constant, min^{-1} τ: time required to retain 50% of the initial adsorbate	Yoon and Nelson [25]
$\frac{C}{C_0} = 1 - \frac{1}{1+\left(\frac{C_0\, V_{eff}}{q_0\, m}\right)^a}$	a: empiric parameter	Yan et al. [26]

Source: [23-26].

III. RESULTS AND DISCUSSIONS

III.1 BATCH ADSORPTION STUDY

The relation between the adsorption capacities in function of contact time for different temperatures is shown in Figure 1. The adsorption capacity increased 1.4 times as the contact time increased from 5 to 15 minutes. Also, in the first 5 minutes about 65%, 78% and 65% of the equilibrium adsorption capacity was reached for 27, 40 and 60 ºC, respectively. Qadeer and Rehan reported the phenol adsorption with activated commercial coal and found that the time to reach the equilibrium was five minutes [27-29]. This can be explained by high availability of active sites on the SBFA surface at the beginning of the process [7].

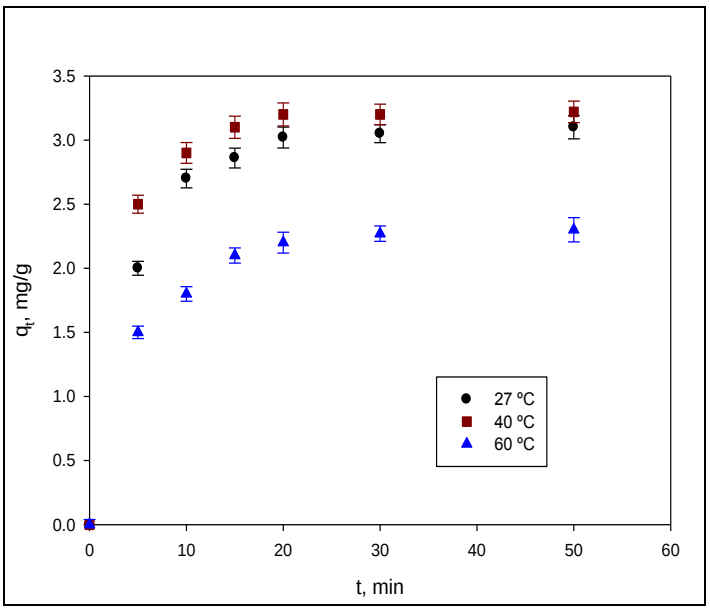

Figure 1: Experimental adsorption capacities in function of contact time at different temperatures.
Source: Authors, (2020).

The experimental results provided in Figure 1 have been fitted by linear regression to the three kinetic models considered in material and methods section: pseudo-first order, pseudo-second order and intraparticle difussion models. Figures 2, 3 and 4 show the results of the fit at the three temperatures tested.

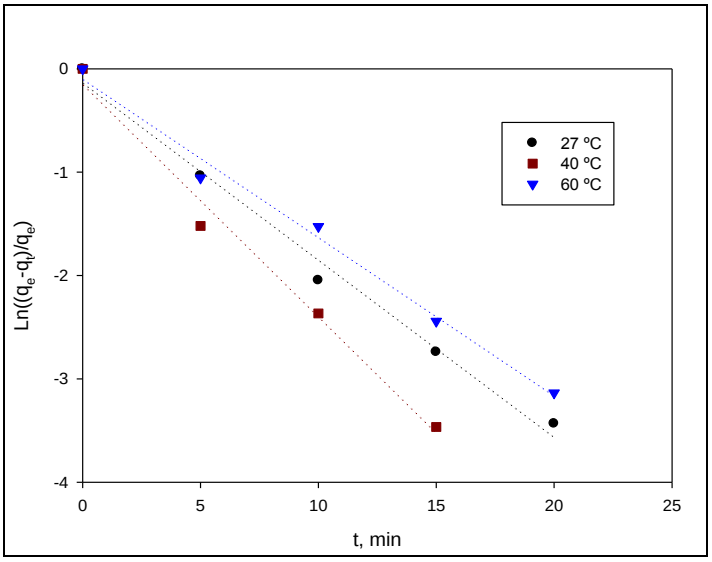

Figure 2: Pseudo-first-order adsorption kinetics of phenol on SBFA.
Source: Authors, (2020).

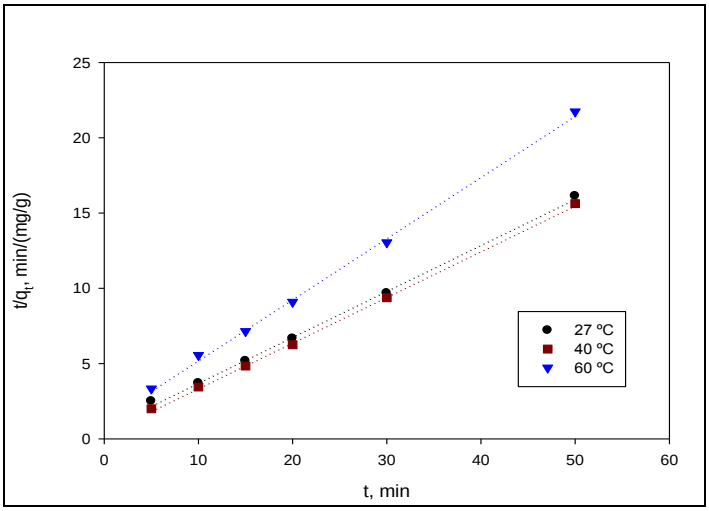

Figure 3: Pseudo-second-order adsorption kinetics of phenol on SBFA.
Source: Authors, (2020).

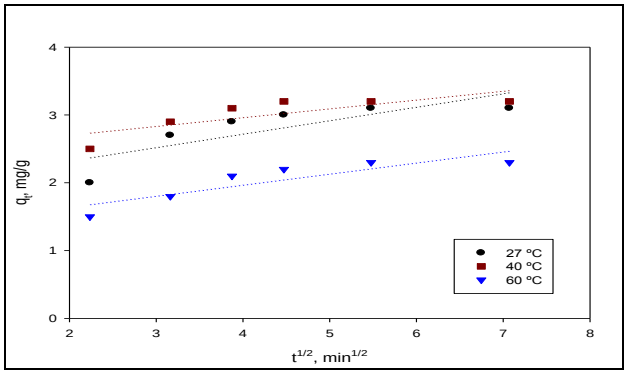

Figure 4: Intraparticle diffusion adsorption kinetics of phenol on SBFA.
Source: Authors, (2020).

Table 4 reports the values of the model parameters calculated from the linear fitting. Results show that, in pseudo-first-order and pseudo-second-order models, higher values of R^2 were found and the calculated values of q_e were comparable to those of experimental values. Also, data exposed that, in general, the pseudo-second-order model was the more adequate to reproduce the experimental data. It indicates chemical adsorption onto phenol removal by SBFA [30]. Intraparticle diffusion model did not fit well to the process of adsorption of phenol due to the low values of R^2 obtained, especially for temperatures of 27 and 40 ºC. Intraparticle diffusion model fitted the experimental results in a lower degree.

Table 4: Kinetic parameters for the adsorption of phenol on SBFA.

Models	Parameters	Temperature		
		27 °C	40 °C	60 °C
Pseudo-first-order	$k_1(min^{-1})$	0.21	0.30	0.19
	$q_{e\ Calc.}(mg/g)$	3.08	3.17	2.26
	R^2	0.998	0.988	0.968
Pseudo-second-order	$k_2(g/mg{\cdot}min)$	0.13	0.26	0.14
	$q_{e\ Calc}(mg/g)$	3.27	3.30	2.46
	R^2	0.999	0.999	0.998
Intraparticle diffusion	$k_{id}(mg/g{\cdot}min^{1/2})$	0.20	0.13	0.16
	$C(mg/g)$	1.93	2.45	1.32
	R^2	0.665	0.641	0.771

Source: Authors, (2020).

According to some previous works, temperature has an evident influence on adsorption of both gas and liquid substances The maximum sorption capacity q_e calculated from pseudo-first and pseudo-second order models decreased as the temperature increased, mainly when temperature changed from 27-40 to 60 ºC. Some authors [31-33], reported that, when the temperature increased, the attraction between the adsorbate and the active groups of the solid surface weaken and there was a greater inclination of the adsorbate to discharge from the solid surface towards the liquid phase, which causes a drop in adsorbate adsorption.

III.2 COLUMN ADSORPTION STUDY

Studies of adsorption in fixed-bed or packed-bed columns are indispensable for the scale-up of the adsorption processes [34-35]. In this sense, to determine the kinetic parameters that characterizes dynamic adsorption is important carry out research that lets determinate the corresponding breakthrough curves.

In the Figures 5 and 6, the breakthrough curves show saturation times from 110 and 150 min for 47.5 and 65.0 g respectively.

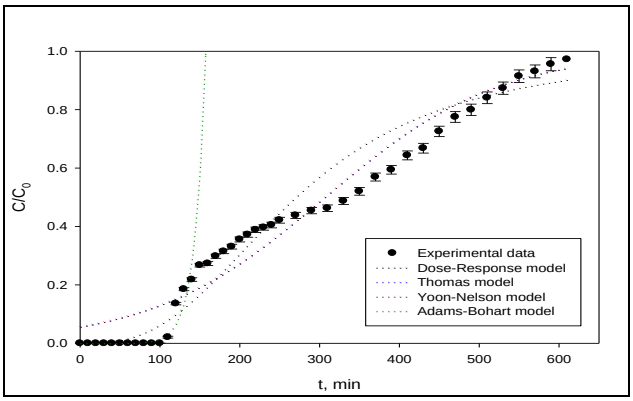

Figure 5: Non-linear plot of Thomas, Yoon-Nelson, Adams-Bohart and Dose-response models for the adsorption of phenol using 47.5 g of SBFA.
Source: Authors, (2020).

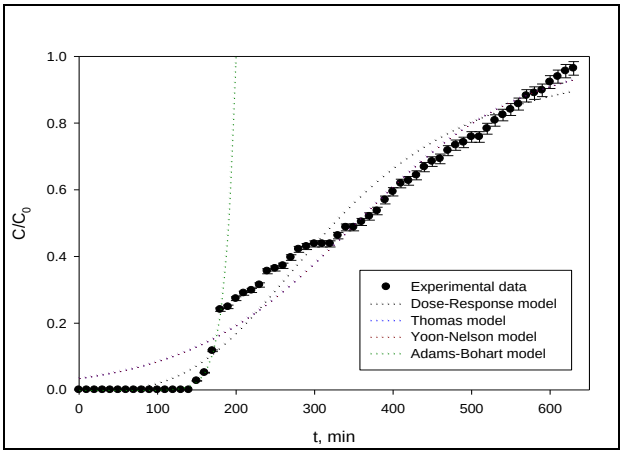

Figure 6: Non-linear plot of Thomas, Yoon-Nelson, Adams-Bohart and Dose-response models for the adsorption of phenol using 65.0 g of SBFA.
Source: Authors, (2020).

Table 5 shows the parameters calculated from the kinetic models, applied to the breakthrough curves, for both experiments performed with different weight of adsorbent.

Table 5: Kinetics parameters in dynamic conditions for the adsorption of phenol on SBFA.

Models	**Parameters**				
Dose-response	***m**(ash)(g)*	***A***	***q_0** (mg/g)*	***R^2***	
	47.5	2.72	0.34	0.867	
	65.0	3.26	0.30	0.908	
Thomas		***k_{TH}** (mL/min·mg)*	***q_0** (mg/g)*	***R^2***	
	47.5	0.00184	0.39	0.896	
	65.0	0.00187	0.32	0.917	
Yoon-Nelson		***k_{YN}** (min^{-1})*	***τ** (min) calc.*	***R^2***	***τ** (min) exp.*
	47.5	0.0092	306.3	0.896	330
	65.0	0.0094	351.5	0.917	360
Adams-Bohart		***k_{AB}** (L/mg·min)*	***N_0**(mg/L)*	***R^2***	
	47.5	0.0146	90.62	0.765	
	65.0	0.0148	88.55	0.998	

Source: Authors, (2020).

According to the results obtained for Dose-response and Thomas models, as the bed height increased, the amount of phenol removed by gram of SBFA, q_0, decreased. In addition, if the values obtained of q_0 for Dose-response and Thomas models are compared, very similar values are found.

The Thomas and Yoon-Nelson fitted better the full experimental breakthrough curve. Adams–Bohart model also represents the sorption of phenol accurately for the initial part of the breakthrough curve and fitted better for the highest mass of adsorbent studied. In all the cases, R_2 and the rate constant values increased with an increase in the sorbent mass, due to increase of the height of the mass transfer zone. Regards the parameter τ of Yoon-Nelson model (the half-life of adsorbate breakthrough) it did not show important differences between the calculated values and the experimental ones.

IV. CONCLUSIONS

From the results obtained it can be concluded that the sorption process occurs quickly, reaching the maximum sorption capacity before 20 minutes of operation, being slightly more favorable at temperatures between 27 and 40 ºC.

The kinetics of adsorption of phenol using SBFA as adsorbent in batch systems was well described by pseudo-first order and pseudo-second order models with R^2 values higher than 0.99 in both models, which suggests that adsorption process was well defined by chemisorption.

The kinetic models used to predict the adsorption of phenols in fixed-bed columns, Thomas, Yoon-Nelson, Adams-Bohart and Dose-response models, fitted well to the experimental breakthrough curves. Although, Adams-Bohart model was only able to predict the initial part of the curve.

V. ACKNOWLEDGMENTS

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RESEARCH ARTICLE OPEN ACCESS

SYSTEMATIC MAPPING APPROACH TO SUPPORT ADMINISTRATION QUANTITATIVE RESEARCH

Sanderson de Paula Barbosa[1], Franklin da Silva Nonato[2], André Luiz de Castro Leal[3] and Márcio Zamboti Fortes*[4]

[1, 2, 3] Federal Rural University of Rio de Janeiro - UFRRJ. Seropédica–Rio de Janeiro, Brazil.
[4] Federal Fluminense University - UFF. Nitéroi–Rio de Janeiro, Brazil.

[1]http://orcid.org/0000-0002-7143-4733, [2]http://orcid.org/0000-0002-8624-6575, [3]http://orcid.org/0000-0002-8206-0992, [4]http://orcid.org/0000-0003-4040-8126

Email: *mzamboti@id.uff.br

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ABSTRACT

This paper explores guidelines for the execution of quantitative research on a specific topic. Using a systematic mapping, as explained here, it is possible to obtain large numbers of scientific publications and properly analyze them to achieve a better understanding of state-of-the-art research, overall topic maturity, and its relevance through time. Additionally, systematic mappings provide answers to research questions as defined by the researcher conducting the process, allowing for further exploration of specific knowledge concerning the studied domain. In this study, the topic of 4.0 Industry is analyzed to illustrate the process and its results.

I. INTRODUCTION

The guidelines compose a systematic mapping method. It is a method of building a classification scheme and structuring a field of interest and for structuring a broad research field concerning research questions about contents, methods, and trends in the available publications. The analysis of results focuses on frequencies of publications for categories within the scheme; thereby, the coverage of the research field can be determined. There are distinctions between mapping studies and conventional systematic literature review (SLR) [1]. The mapping studies provide a more detailed review of the topics covered in each primary study including issues such as major outcomes and quality evaluations of primary studies [2].

We intend to demonstrate the guidelines for this technique by using it to find and classify the scientific works, in this applied in 4.0 Industry [3]. It is important to identify the available literature, authors, period, type of model, applications to understand the universe of research about this domain and the state of the art. The strategy consists to specify questions, data extraction in the digital data sources (libraries), automatic searches, analysis, categorizations, tabulations, plot graphs and to demonstrate explicitly the method used thus setting a systematic mapping.

The present study will be presented in sections like Section 2, related words; section 3, systematic mapping process; section 4, results from presentation; section 5, conclusions.

II. RELATED WORKS

It is possible to find in the literature several papers about systematic mapping writing by authors from different areas of knowledge.

The authors [4] investigated research related to established service level agreements to ensure quality control of services provided by cloud servers to consumers and businesses. They have developed a systematic study and mapping of how SLAs are being managed. Thus, 328 surveys were studied and classified into seven technical categories. In this way, it was possible to map the types of research, their contributions, and demographic information from these studies. Thus, the authors identified not only the SLA

management models but the gaps in the studies of this administrative tool.

For [5] discuss several guidelines and empirical studies that can be used to improve the quality of ongoing research and they discuss the likelihood that we can use meta-analysis to combine the results of related studies. The authors propose a specific guideline, based on your experience in software engineering with backgrounds in statistics as well as computer science, and relate the problems with standard statistical procedures in software experiments. They propose to show a guideline to assist administration researchers to avoid major pitfalls in their research activities and to report their research correctly.

According [6] studied eighty studies on business process variability, which is the phenomenon known as the changes in the business processes of companies that occur due to the dynamic environment in which they operate. With the systematic mapping carried out, a conceptual synthesis on the subject was established, in addition to establishing opportunities for future research. They researched what are the main characteristics of process variation, the approaches that are available, and what are the current challenges in managing process variations in the business world.

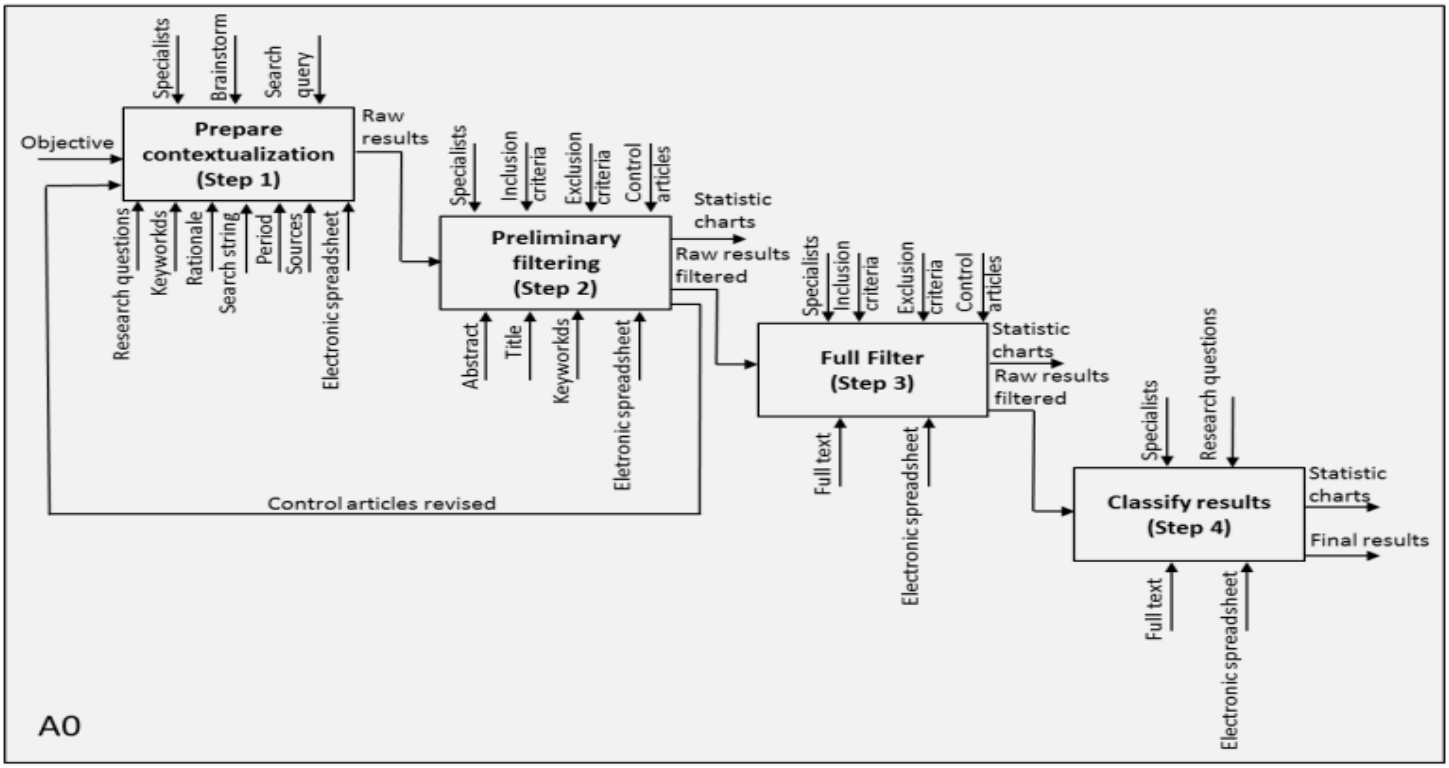
For [2] suggested that software engineers and empirical software engineering researchers should adopt the evidence-based practice as pioneered in the fields of medicine and sociology. In this paper, the author explores the aspects of software engineering in several scientific publications considering a string associating software engineering and other terms as a review of studies, structured review, systematic review, literature review, literature analysis, and others. With this, the authors consider the relationships between systematic literature review topics and the software engineering undergraduate curriculum.

According [7] develop a systematic mapping of the software engineering field. The results were focused on frequencies of publications for categories. The objective of the authors was to demonstrate conduct to make a systematic mapping study in software engineering. In the work, the authors discuss the difference in the goals, breath, validity issues, and implications between systematic mapping and reviews.

III. THE SYSTEMATIC MAPPING PROCESS

III.1 MAIN PROCESS

The method to apply systematic mapping was done in steps. Figure 1 shows the step by step of the systematic mapping process. It is the main process (in macro vision). To describe the process, we will use a Structured Analysis and Design Technique (SADT) model [8] (Figure 1), where the following activities are mentioned: Step 1: Prepare Contextualization; Step 2: Preliminary filtering; Step 3: Full filter; Step 4: Classify results. These activities represent the context diagram (A0).



Source: Authors, (2020).

The SADT structure contains an arrow pointing into the left side of a box represents things that will be transformed by the box, these represent inputs. An arrow pointing down into the top of the box represents the control that affects how the box transforms the things entering from the left side. Arrows entering the bottom of a box represent mechanism and provide the analyst with the ability to document how the function will operate, who will perform it, or what physical resources are needed to perform the function. Text labels to describe boxes and arrows and text to define the precise meanings of diagram elements.

For each step was done a set of activities will be described below.

III.2 PREPARE CONTEXTUALIZATION (STEP 1)

The first effort was reuniting the group of specialists and discuss together, in a brainstorming strategy, what and how

elements could help achieve the objective. The specialists were formed by three researchers on the field of information systems and technology.

According to the first step (Step 1) of the context diagram, many elements were defined. It was defined as structural elements and contents.

The first structure element defined was Objective. This represents the principal goal of the research. It was defined as 'To know state-of-the-art research on 4.0 Industry'.

The definition of the objective and other structures was established in the first activity of the main systematic mapping process. Figure 2 shows that the process is composed of two activities. In the first (1.1), the specialists configure the structures that will use in filters and, in the second (1.2), they execute a query to filter the preliminary results.

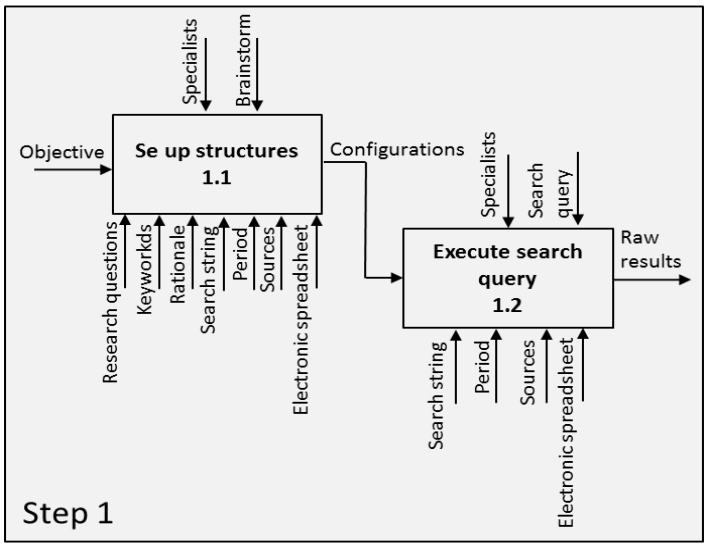


Figure 2: SADT of the systematic mapping process.
Source: Authors, (2020).

The structures and contents were defined as presents bellow and are results of 1.1 Set up structures:

i) Research questions (mechanism):

The specialists formulate research questions as guidelines to analyze and to rank the articles. Answering these research questions (RQs) is the main purpose of the systematic mapping, thus, they must be elaborated in such a way as to provide an overview of the subject matter and any specific information that the study seeks to uncover.

Common examples of research questions are 'When have the studies been published?' allowing the mapping to uncover the progress of publication quantity through time; or 'Where have the studies been published?' which helps to understand the maturity of said research, considering which venues (journals, conferences, etc.) have hosted these publications. More specific RQs are also used, to uncover more valuable information on the subject.

ii) Search Strings (mechanism):

The strings are used to search the web in some source (discussed below). They are defined in two times. The first list of terms with:

P = ('Industrial Management and Control 4.0')

Q = ('monitoring' OR 'control' OR 'application' OR 'analysis' OR 'structure' OR 'steel industry' OR 'siderurgy' OR 'method')

R = ('industry 4.0' OR '4th industrial revolution' OR 'industrial 4.0')

Search String = P ^ (Q v R)

In the final, the search string was defined as:

(Industrial Management and Control 4.0) AND ('monitoring' OR 'control' OR 'application' OR 'analysis' OR 'structure' OR 'steel industry' OR 'siderurgy' OR 'method') OR ('industry 4.0' OR '4th industrial revolution' OR 'industrial 4.0').

iii) Source (mechanism):

The search string was used in searches into some sources in the scientific libraries. The sources selected to the search were:

-SpringerLink, Web of Science ('https://link.springer.com/');

-Engineering Village ('https://www.engineeringvillage.com/');

- Scopus ('https://www.scopus.com/').

However, this work was used just the that are below

- ACM Digital Library ('https://dl.acm.org/');

-IEEE Xplore ('https://ieeexplore.ieee.org/Xplore/home.jsp');

- Science Direct ('https://www.sciencedirect.com/').

The intention is to catch studies on conferences and journals in the specific domain.

iv) Period (mechanism):

The search was done in a period of 'initial year' and 'final year', eg. 2000 to 2019.

v) Area (mechanism):

The searches were done in the Administration area.

vi) Inclusion Criteria (IC) (mechanism):

The publication presents information on some kind of 4.0 Industry management and control (for any reason) (IC1). It was used as a first filter and to explain the guideline.

vii) Exclusion Criteria (EC) (mechanism):

The specialists established some exclusion criteria. These were used to dispose of articles. The established criteria were:

- It does not provide an abstract (EC1).
- It is just an abstract (EC2).
- It is not written in English (EC3).
- It is a copy or an older version of another publication that has already been considered (EC4).
- It is not a primary study (e.g., editorials, summaries of keynotes, tutorials, etc.) (EC5).
- It is not possible to have access to the full version of the publication (EC6).

viii) Control Articles (CA) (mechanism):

Control Articles (CAs) are manually selected publications concerning the subject meant to be amongst the results yielded by the RQs. When possible, these may be well-known publications, as they are meant to provide a baseline on the type of article the study is meant to cover.

For this guide, on the subject of 4.0 Industry, the CA selection was as follows.

For this guide, on the subject of 4.0 Industry, the CA selection was as follows: Smart Factory of Industry 4.0: Key Technologies, Application Case, and Challenges [9], When Time Matters: Predictive Mission Planning in Cyber-Physical Scenarios [10], Big Data-Oriented Product Infant Failure Intelligent Root Cause Identification Using Associated Tree and Fuzzy DEA [11], Development of an instrument for the assessment of scenarios of work 4.0 based on socio-technical criteria [12], An ontology-based framework for the management of machining information in a data mining perspective [13], Complex System Health Management Based On Condition Monitoring And Test Data [14], Simulation-based dynamic shop floor scheduling for a flexible manufacturing system in the industry 4.0 environment [15].

ix) Structure (mechanism):

After structure elements and their respective contents were configured, the specialists elaborate the electronic spreadsheet. The spreadsheet helps to organize the results and accounts for them. The organization of the first elements was organized in rows in columns as presented below. These elements serve as input to the search query (output of Step 1 - Prepare contextualization).

Table 1: Electronic spreadsheet with configuration elements.

Objective:	To know state-of-the-art research on 4.0 Industry	
Research Questions	**Rationale**	
RQ1	When was it published? What is the research period?	To explain more details about such research questions
RQ2	Where is the subject being published more frequently?	
RQ3	What is the approach of research on production line control systems, in the Brazilian steel industry, within the strategy of industry 4.0?	
RQ4	How are steel companies being structured about production line control departments?	
RQ5	How is the Brazilian steel industry working with industry 4.0 about condition control of production lines?	
RQ6	What is being researched / studied about industry 4.0 correlated with theories of strategic management of industrial production?	

Source: [3].

Search String: see ii) Search Strings (mechanism) section.
Period: see iv) Period (mechanism) section.
Area: see v) Area (mechanism) section.
Sources: see iii) Source (mechanism) section.

Inclusion Criteria

IC1 - The publication concerns the subject of… ((vi) Inclusion Criteria (IC) (mechanism)).

Exclusion Criteria

see vii) Exclusion Criteria (EC) (mechanism) section.

Control Articles

CA1, CA2, CA3, CA4, CA5, CA6, CA7. see viii) Control Articles (CA) (mechanism) section.

After the initial configurations prepared, it is possible to execute the search query (1.2 Execute search query).

x) Raw Results (output):

The raw results were the first results achieved after the execution search query through the mechanisms and controls.

The results were listed in the sheet as presents in the example of Table 2 (partial vision). In this sheet, we list all publications returned by the search query in all sources, without eliminating duplicates (same publication returned by different sources - see iii) Source (mechanism) section). Publications should be sorted by source. Publications present in multiple sources should appear in the list of each source.

Table 2: Electronic spreadsheet with raw results model [3].

Article	Source	Year	Title
[16]	ScienceDirect	2017	Research on Big Data – A systematic mapping study
[9]	in IEEE Access	2018	Smart Factory of Industry 4.0: Key Technologies, Application Case, and Challenges
[10]	in IEEE Access	2019	When Time Matters: Predictive Mission Planning in Cyber-Physical Scenarios
[17]	in IEEE Access	2018	A Cloud-Based System for Improving Retention Marketing Loyalty Programs in Industry 4.0: A Study on Big Data Storage Implications
[11]	in IEEE Access	2019	Big Data-Oriented Product Infant Failure Intelligent Root Cause Identification Using Associated Tree and Fuzzy DEA
[18]	in IEEE Access	2018	Practical Guide to Smart Factory Transition Using IoT, Big Data and Edge Analytics
[12]	ACM Digital Library	2018	Development of an instrument for the assessment of scenarios of work 4.0 based on socio-technical criteria
[19]	in IEEE Access	2018	Exploiting Industrial Big Data Strategy for Load Balancing in Industrial Wireless Mobile Networks
[20]	in IEEE Access	2019	IEEE Access Special Section Editorial: Key Technologies for Smart Factory of Industry 4.0
[21]	ACM Digital Library	2019	Data Analytics and BI Framework based on Collective Intelligence and the Industry 4.0
[13]	ScienceDirect	2018	An ontology-based framework for the management of machining information in a data mining perspective
[14]	in IEEE Access	2018	IEEE Access Special Section Editorial: Complex System Health Management Based On Condition Monitoring And Test Data
[22]	in IEEE Access	2017	Industrial Big Data Analysis in Smart Factory: Current Status and Research Strategies
[23]	in IEEE Access	2018	Industrial Big Data Analytics for Prediction of Remaining Useful Life Based on Deep Learning
[15]	in IEEE Access	2017	Simulation-based dynamic shop floor scheduling for a flexible manufacturing system in the industry 4.0 environment

Source: Authors, (2020).

III.3 PRELIMINARY FILTERING (STEP 2)

In the preliminary filtering, the specialists execute two activities. They filter the publications and classify them. Figure 3 shows these two activities.

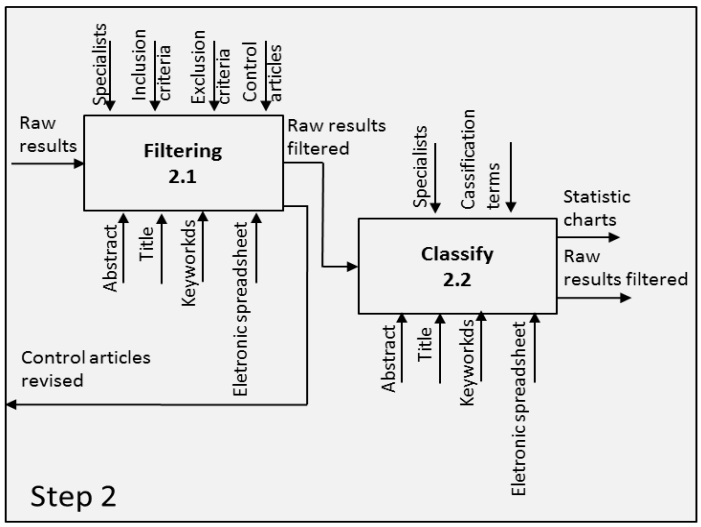


Figure 3: First filter and classification.
Source: Authors, (2020).

The Filtering (2.1) activity has as a first aim the unification of publications present in multiple sources. After this, the results list got 921 occurrences of distinct publications.

After unifying publications, each publication should be analyzed against the selection criteria (ICs and ECs) considering Title, Abstract, and Keywords only. When the analysis indicates the item satisfies all inclusion criteria, the analysis should read 'OK'. In case it points to the exclusion of the item, you should indicate if the publication doesn't satisfy an inclusion criterion (e.g., ~IC1) or if it satisfies an exclusion criterion (e.g., EC5). The ECs are more than one, the identification criteria are marked with EC1, EC2, EC3, EC4, EC5, and EC6.

Through analysis of title, abstract, and keywords, publications that did not meet all inclusion criteria or met any of the exclusion criteria have been removed. Among the occurrences were found in the CAs.

The Classify activity (2.2) identifies publications according to a categorization. In addition to the answers given RQs, these were complemented by categorizations. To the RQ6 was detached the year of the publication and de venue, this last categorized by the acronym of the event name. This information, standardized, is important to plot graphs. But, for RQ7, there was a concern to focus on relevant information on the quality and maturity of publications and communities in which they were found. We suggest three categories have been proposed to analyze the relevance: Venue Type (after reading found the types Journal, Chapter, Conference, Symposium, and Workshop), Impact Factor, and Scholar Citation, but to exemplify here, we used venue type.

III.4 FULL FILTER (STEP 3)

In this step, each publication should be analyzed against the selection criteria (ICs and ECs) considering its full text. The Analysis column works exactly like the one in the previous step (1st filter, eg., OK, ~IC and EC). Figure 4 shows the activity (unique) for each of these steps.

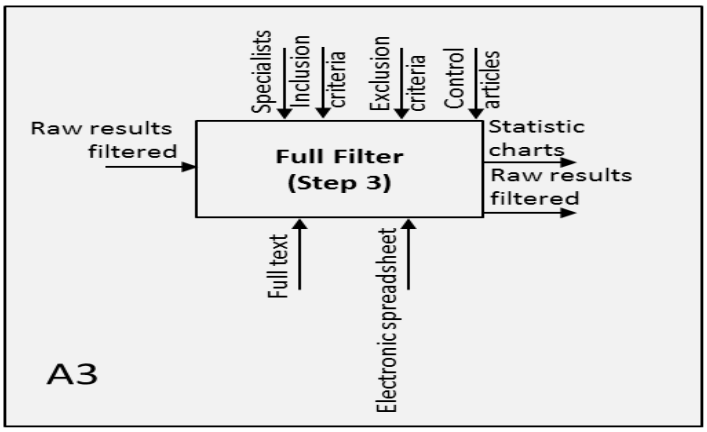


Figure 4: Filter in the full papers.
Source: Authors, (2020).

We can consider a study with 144 occurrences as final results according to the initial criteria and the resume of the evolution of realized filters can be seen in Table 3. The sequence of activities is duplicated removal, to found the CAs and verification of IC and ECs criteria.

Table 3. Results from the selection stages.

Applied Criteria	Analyzed Content	Initial Occurrences	Final Results	Reduction (%)
Duplicated Removal	Title, abstract and keywords	1595	921	42,26
CAs	Title, abstract and keywords	7	7	0
IC and ECs (1,2,3,4,5,6)	Title, abstract and keywords	921	206	77,63
IC and ECS (1,2,3,4,5,6)	Full text	206	144	30,10
Final Result	-	1595	144	90,97

Source: [3].

III.5 CLASSIFY RESULTS (STEP 4)

While reading the full text, the specialist should try to answer and review all RQs. But particularity for this activity, the specialists are also concerned at the categorization of questions and the focus given to the RQ1 and RQ3.

Figure 5 presents the input, control, mechanism, and output of the classifying results process.

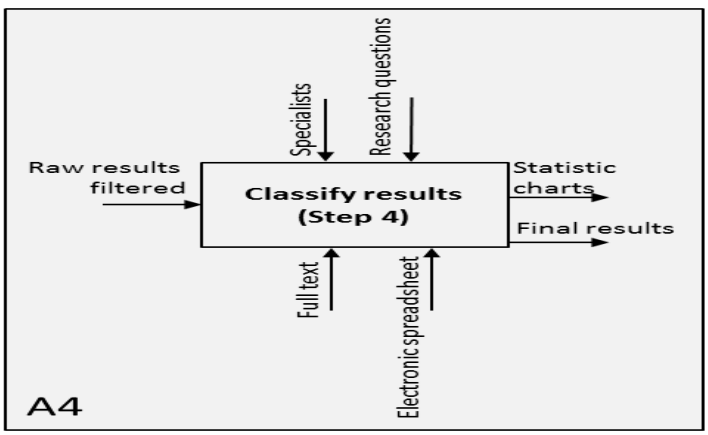


Figure 5: Using Research Questions.
Source: Authors, (2020).

IV. RESULTS

It is important to realize that as output results of the activities of the systematic mapping process were generated numeric graphics, but the results of systematic mapping will be presented from two perspectives: from numerical graphs of the column data and qualitative analysis of the texts captured and described in the columns for research questions. The results were made on the final occurrences and it presents for each research question in the sections below. Figures 6 to 11 show examples of these results demonstration. Tables 4 and 5 are a summary of these data.

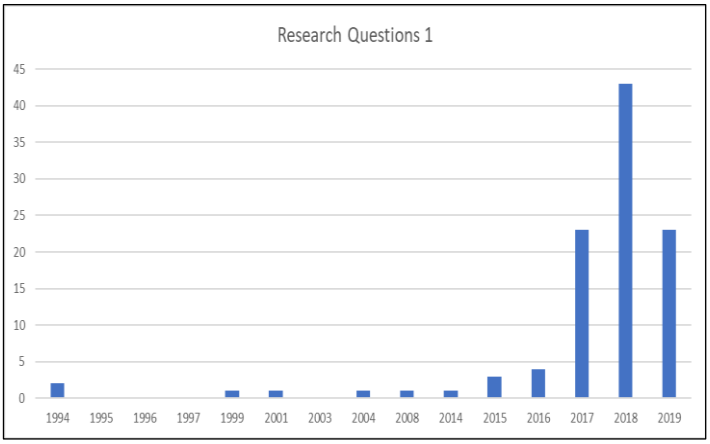


Figure 6: Distribution of publications per year.
Source: [3].

All papers acquired and quantified on the raw results section are initially assigned IDs, which are used to identify such papers in the tables and Appendix. During the filtering process, however, many of these are removed due to not being part of the studied topic. Because of that, IDs are not always numbered in an appropriate sequence but instead leap from number to number to account for removed paper IDs. As such, despite having IDs up to [15], this does not reflect that ninety-six papers were considered in the study.

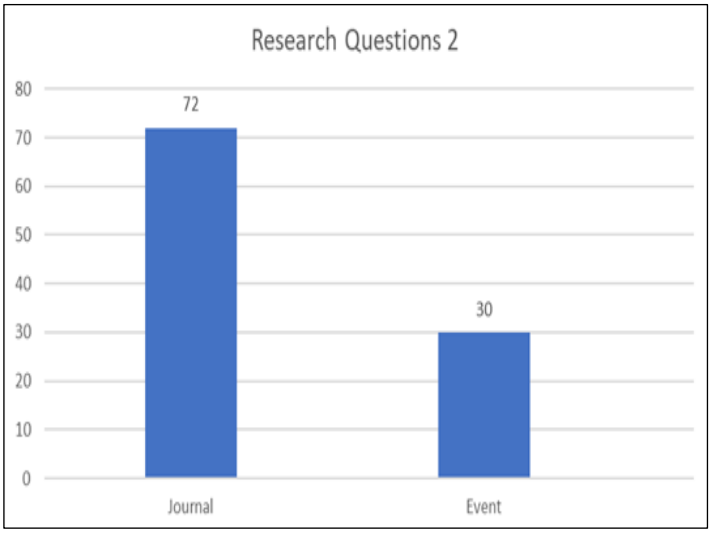


Figure 7: Distribution of publications per venue type.
Source: [3].

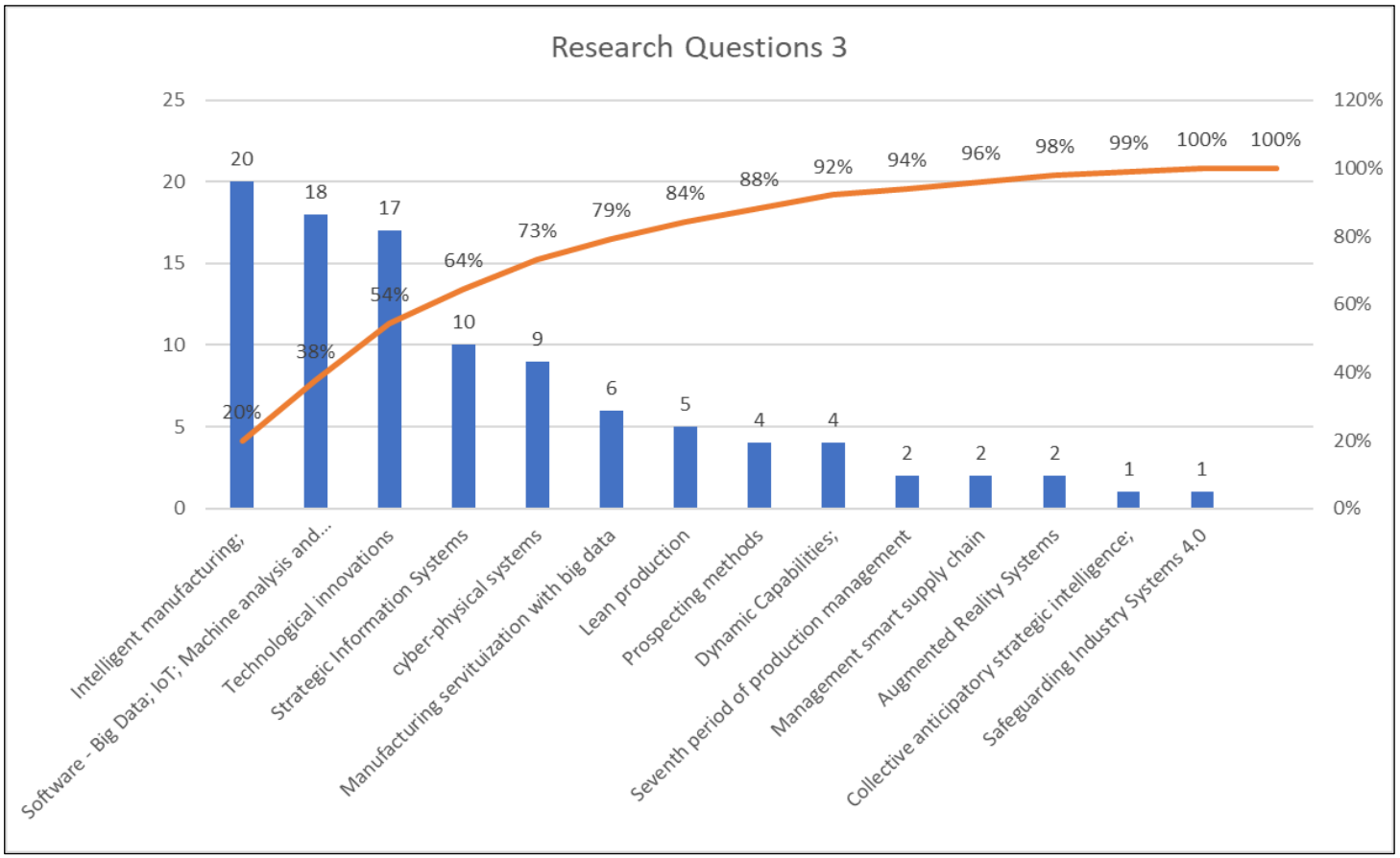


Figure 8: What is the approach of research on production line control systems, in the Brazilian steel industry, within the strategy of industry 4.0?
Source: [3].

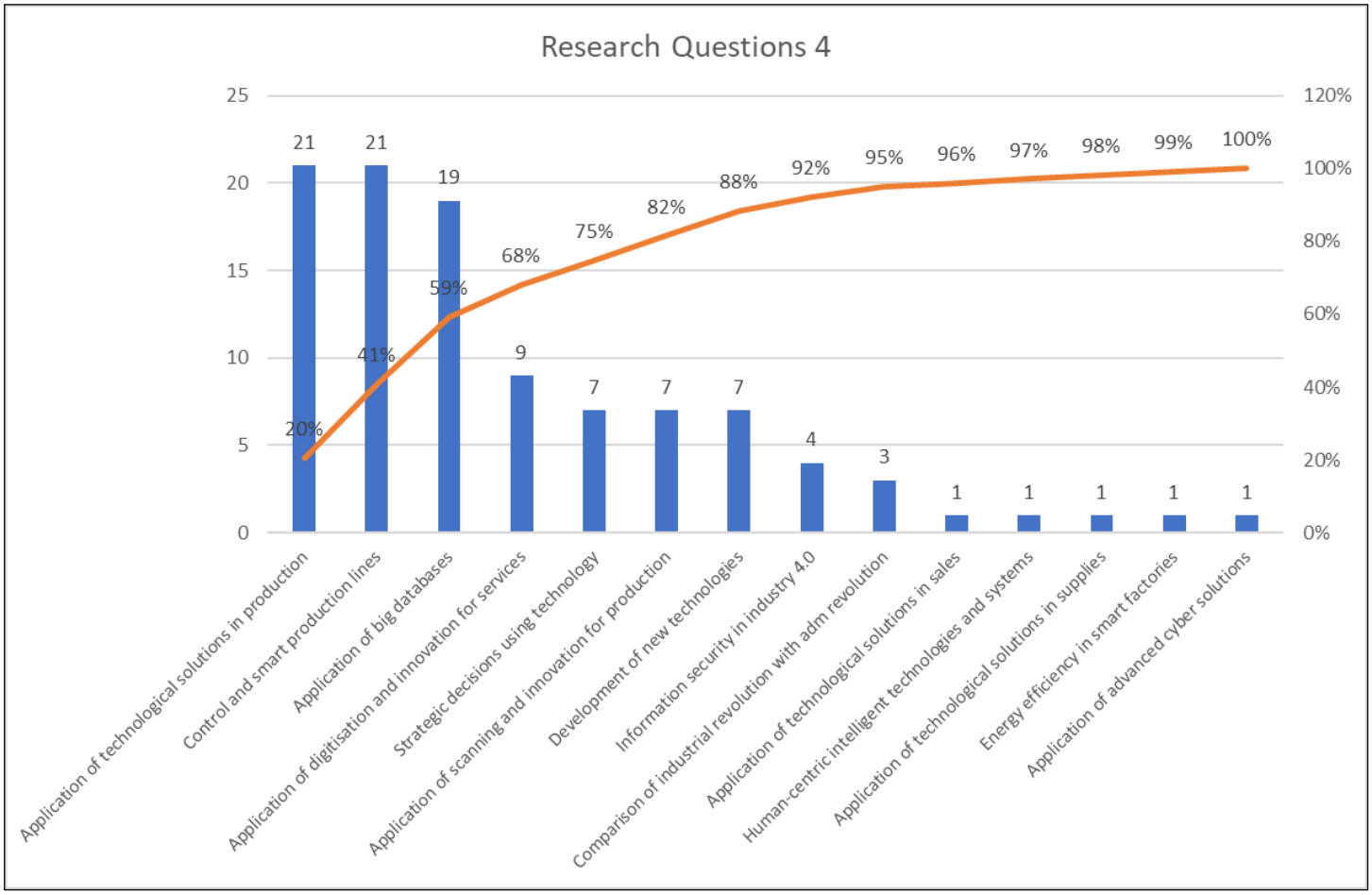


Figure 9: How are steel companies being structured about production line control departments?
Source: [3].

Table 4: Categories of the second research question.

Category	Description	Number of articles
Journal	Article published in scientific journals.	[16], [9], [17], [11], [18], [19], [20], [13], [14], [22] and [23].
Event	Article published in congresses and seminars.	[12], [21], and [15].

Source: [3].

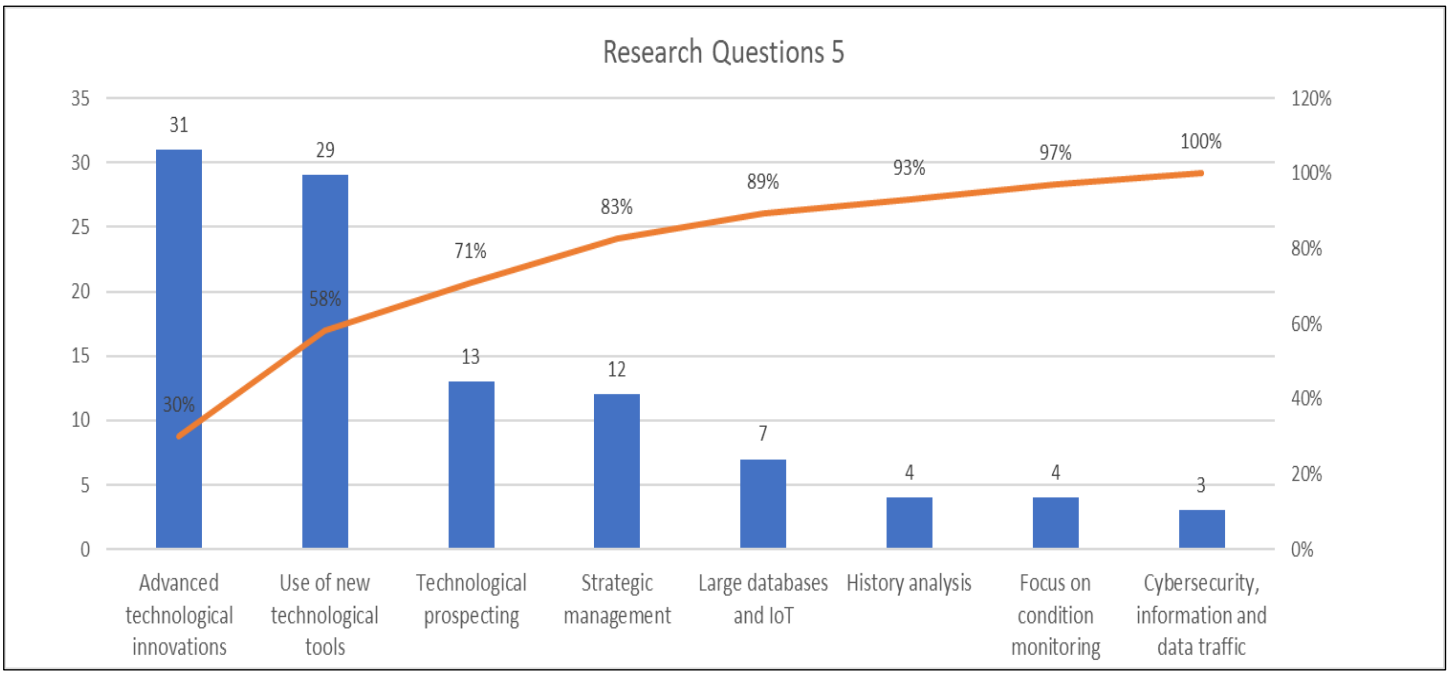


Figure 10: How is the Brazilian steel industry working with industry 4.0 about condition control of production lines?
Source: [3].

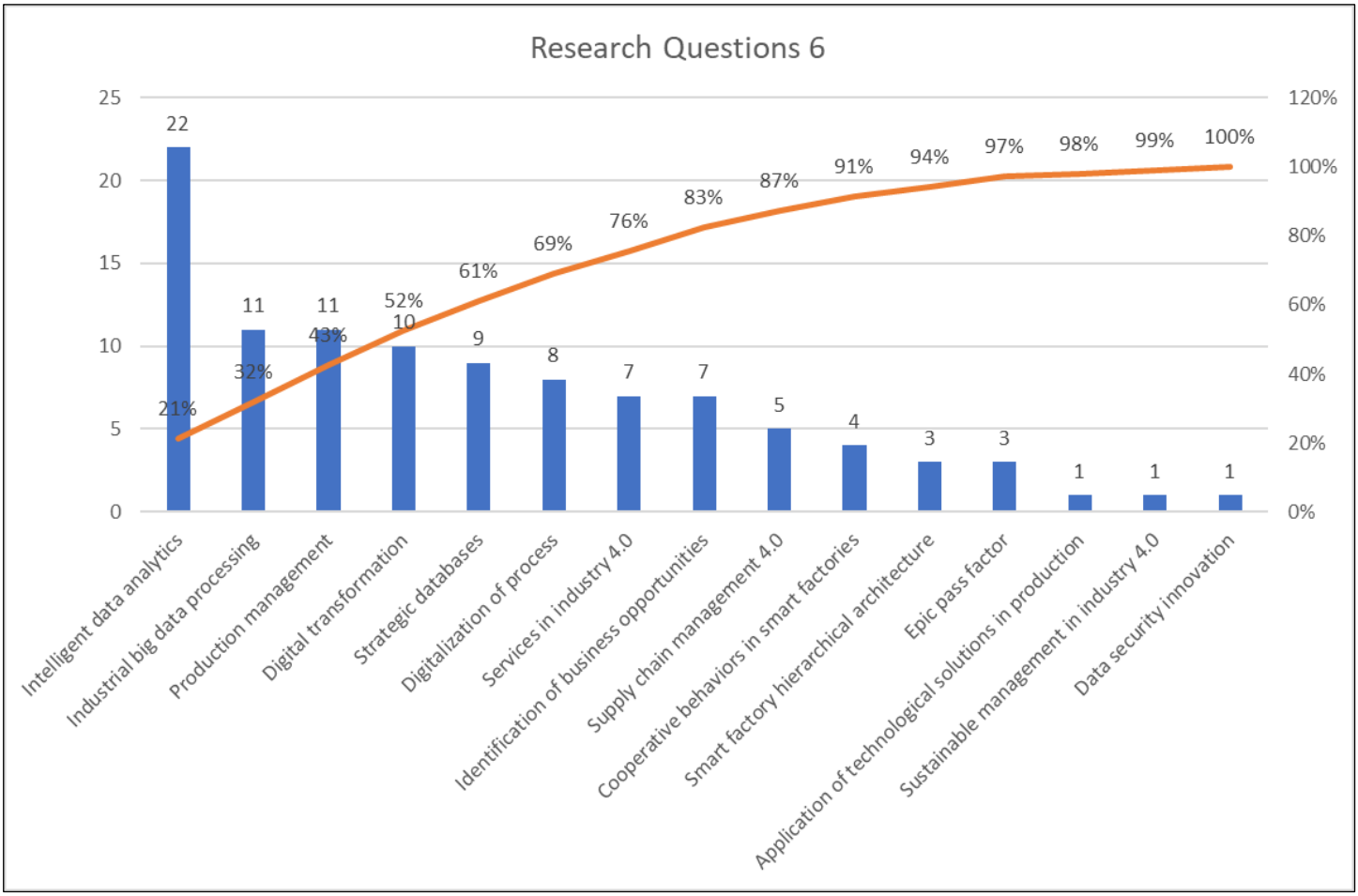


Figure 11: What is being researched / studied about industry 4.0 correlated with theories of strategic management of industrial production?
Source: [3].

Table 5: Categories of the fifth research question.

Category	Description	Number of articles
Advanced technological innovations	Development of advanced technologies.	[16], [17], [11], [18], [12], [19], [21], [13], [22], and [23].
Technological prospecting	Development of new businesses using technology.	[9] and [20].
Cyber security, information, and data traffic	Focus on cyber-physical systems and data security management.	[14] and [15].

Source: [3].

It is important to describe a quantitative and qualitative analysis for each exposed graph. The discussions made by the researchers for each graphic help the readers to understand not only the static portrait exposed in the graphic but also the perception of the researchers about the investigated.

The categories presented in each graph are listed by the researchers according to the course of the study, that is, as they find the occurrence, the researchers quantify and analyze the groupings found. The groupings of the groupings and the scale of occurrences help in answering the research questions initially formulated. The understanding of the investigated domain arises as the researcher finds the answers, the number of occurrences, the groupings. Thus, by analyzing an isolated graph or analyzing the situation of one or more graphs, it is possible to understand the domain and problem investigated. The organized structure of the research based on steps and technical criteria used in an orchestrated way make up the systematic mapping.

V. CONCLUSIONS

The present work had as objective to present a practical guide on the scientific method of systematic mapping to support researchers in the field of administration in their studies on the state of the art of their research domain and to find answers for research questions that could provide us with a panorama of this area. The work presented the step by step of how to elaborate a systematic mapping and the results presented here are part of more consistent and comprehensive research on 4.0 Industry. Thus, they were explained succinctly only as examples of applying results from a systematic mapping. As already mentioned, the researchers need, for each graph, to establish discussions about their perceptions of the graph presented and the influence of the results in the investigated domain.

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APPLICATION OF OPERATIONAL RESEARCH IN PROCESS OPTIMIZATION IN THE CEMENT INDUSTRY

Marcelo Carneiro Gonçalves[1], Arthur Beltrame Canciglieri[2], Karolina Miranda Strobel[3], Matheus Felipe Antunes[4] and Rafaela Richa Zanellato[5]

[1, 2, 3, 4, 5] Pontifical Catholic University of Paraná - PUCPR. Curitiba–Paraná, Brazil.

Email: carneiro.marcelo@pucpr.br, artcanci_98@hotmail.com, karolstrobel@gmail.com, matheusantunesfelipe@gmail.com, rafazanellato@hotmail.com

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ABSTRACT

One of the largest economic sectors in Brazil is the construction industry, being an important segment for investments in the country. As a result, it is a firmly established sector which has attained a high level of competitiveness. However, given the dynamic approach necessary in a world of accelerated change, the construction industry faces a wide range of challenges which must be addressed so to maintain, and if possible, improve its competitiveness. This study aims to determine how to maximize the profit of a construction company located in Curitiba, Paraná state, applying techniques of Operations Research, an analytical method of problem-solving and decision-making. The tool used to perform the optimization was Linear Programming, a mathematical modeling technique in which a linear function is maximized or minimized when subjected to various constraints. The results show a strong possibility of increasing the company's profit by production leveling.

I. INTRODUCTION

One of the largest economic sectors in Brazil and in the world is that of civil construction, being one of the most important spheres of investment in a country resulting in infrastructure, both at home and for companies and industries. The country's economic result is highly linked to construction indicators, since when a country has a favorable economic scenario, it tends to build and warm up the real estate market. However, in recent years, the Brazilian construction market has fallen due to political and economic instability, resulting in the entire construction materials logistics chain having low sales volume and having to rethink their strategies and costs.

In this context, the largest cement factory in Latin America has three industrial complexes to produce its entire product portfolio, and until 2012 and mid-2013 it was used to its maximum production potential, however from 2013 with crises in the constructions only 1 complex is in operation not reaching maximum production capacity.

In order to reduce the consequences of falling volumes, the company saw the need to reinvent itself and apply new methods of controlling costs and profits, in line with current market scenarios. For this, the product portfolio and how they were offered to the end customer were totally redesigned, in order to facilitate their purchase and use. In addition, the company began to apply simple linear programming methodologies to understand how its production leveling and portfolio could reduce costs and maximize profits.

This work, therefore, aims to apply Linear Programming techniques to maximize the company's profit on top of the main products, that is, only the cement and not the complementary products, considering variables of cost and profit of the sectors of production, commercial and shipping. For that, the 4 main products will be used. In addition, to create a fast and simple linear programming tool, so that managers can make decision-making instantly if the market scenario changes, thus minimizing the impact of future crises and maximizing profit in positive scenarios.

II. THEORETICAL REFERENCE

II.1 OPERATIONAL RESEARCH

According to [1], Operational Research originated during World War II, where the Allied support teams had to solve various

logistical and tactical problems involved in the highly complex military strategy, which would result in saving the lives of their soldiers. Multidisciplinary groups of engineers, physical mathematicians and others were created to solve these problems, in order to preserve resources, whether human or material, since this control would win the war.

Since the end of the war, several companies saw the opportunity to invest in operational research tools and thus maximize their profits and minimize their costs, so that it became popular as a tool already in the reconstruction of post-war destroyed Europe. Currently in Brazil, Operational Research (PO) is an area of Production Engineering that provides professionals with tools for managing an organization's human, material and financial resources. According to [2], applications of PO and its tools are common in different sectors of daily life, such as in industries, in the transport of material and people, in the area of health, education, agribusiness, in the area of finance, in economy and public sectors.

In fact, Operational Research covers a range of areas, models and algorithms that allow managers to make decisions on complex problems. It is possible, in a simplified way, to subdivide the resolution of a problem by the PO in five stages: Problem Formulation (System Identification); Construction of the Mathematical Model; Obtaining the Solution; Testing the Model and the Solution Obtained and its Implementation [3].

II.2 MATHEMATICAL PROGRAMMING

According to [4], programming and mathematical optimization models have two general forms of use. The first type is when the mathematical model is used at the strategic level of the organization, being long-term resolutions and more important decisions, having to evaluate a greater number of variables and their real impact on the organization. The second type of mathematical modeling is used at the tactical-operational level, where the scenario can change daily and the model must be simple and quick to be implemented, without losing its accuracy of reality, serving as a tool for managers to take minor actions.

In the conceptualization of a mathematical model, three main elements are inserted: the first being the decision variables that are the unknowns to be determined by the solution of the model, often being interpreted as the portfolio of products to be produced. The second element being the restrictions: in order to consider, the physical limitations of the system, the restrictions of production and material, of the market, of storage, among others. And thirdly, the objective function: it is a mathematical function that defines the solution based on the decision variables and their restrictions, so that the best answer to the proposed problem is evaluated [5].

II.3 LINEAR PROGRAMMING

According to [6] Linear Programming is a robust planning technique to solve numerous problems. Its results are mainly separated into two elements: the increase in profits and the decrease in costs, being a tool implemented daily in most companies in the world, given its efficiency and speed of modeling. The Linear Programming model is applied to situations of scarce resources, with the intention of reaching a certain objective, usually to maximize or minimize its variables, to choose the best possible scenario within the countless options that can be taken.

[5] conceptualizes linear programming as a tool used to analyze models where the constraints and the objective function are linear - straight. Linear models are versatile tools, of medium mathematical complexity and that require almost no computational effort to find the optimal solution in most of the problems presented. In addition, linear problems and linear programming can be easily contextualized and are easy to understand by the entire body of developers, thus facilitating their understanding and use.

The first great effective model to solve a Linear Programming Problem was the Simplex algorithm, developed in 1947 by Dantzig, which will be addressed in this work. Despite having exponential complexity, which means that when adding variables, the problem grows in complexity of resolution exponentially. Although Simplex is an old method and has several limitations in the representation of more complex problems, it is a model still widely used today, due to its ease of operation and understanding [7].

II.4 SOFTWARE

According to [8] the application of operational research tools has always created a feeling of frustration because they are complex mathematical models and difficult to understand on the factory floor. However, at present several advances have been made to reduce this pain, creating software that simplified its application and thus disseminating the knowledge of operational research. In this context, the Microsoft Excel program created and adapted optimization models through data analysis modules, thus facilitating the use of operational research models with its data tabulation. These tools are now found in the Solver Module, which allows solving optimization problems described through equations written in the spreadsheet cells.

According to [9] with the use of the solver, it is possible to obtain an ideal value (maximum or minimum) for a cell, called an objective cell, obeying the restrictions, or limits, on the values of other cells in a spreadsheet. This creates a very powerful tool for managers, since most of them are already familiar with Excel software and thus can use operational research models to solve problems in a way never seen before.

In addition, the Excel and its complement solver allows the rapid change of scenario and variables within their banknotes, thus making the calculation of an optimal scenario, almost easy for everyone, to make decision making more reliable almost instantly. and ensured in mathematical-scientific methods.

II.5 MODELING

According to [10], modeling is used in several situations that require a solution or decision making. The situation is modeled to simulate possible scenarios that configured alternatives for decision making related to a solution. In other words, modeling offers information to verify the best solutions to a problem and thus find an optimal solution. When it comes to optimization problems, it means that we want to maximize (increase) or minimize (decrease) a function, related to finance, production, among other areas. In such cases, it is necessary to check the objective function and the restrictions presented by the analyzed system.

The first step in modeling is the choice of decision variables. As in most PL problems, the decision variables represent the quantities of products sold, which must be positive values, that is, greater than zero. The second step is to create the

constraints and define the objective function of the problem. In the objective function, it must represent the main objective of the problem, which can be to maximize profit or minimize costs, for example, while the restrictions can be capital, quantity and/or space, they are usually variables such as availability of raw material, capacity production, labor and price limitations [11].

According to [12], when defining the problem restrictions, you must first check the factors that may limit production, so that it is then possible to obtain the optimal solution considering the most important factors of the company. The simplex method seeks, if any, one or more solutions from a basic feasible solution, generating a sequence of feasible solutions. When this sequence is completed, the optimal solution is obtained.

III. DEVELOPMENT

As already mentioned, the company under study operates in the civil construction area, producing cements, mortars, concrete and aggregates. This work focused only on the production of cement, which is divided into 4 types. They differ in the area of construction that are applicable and for that use different amounts of some raw materials such as plaster, slag and and pozzolana.

The company uses four major pillars as the north, they are: Focus on the customer, always aiming at the customer's need, having specific business models to serve the customers. The second pillar is People with Autonomy, which seeks to value leaders by creating strong, diverse and engaged teams, always working together creating solutions, seeking smart synergies aiming at gains for all. The third pillar is Operational Excellence using performance monitoring and always seeking continuous improvement by making decisions with speed, discipline and consistency, maximizing productivity in all areas. And the last pillar of Sustainable Practices, always placing safety in first place, acting ethically and always in accordance with the laws, also promoting eco-efficiency.

Always seeking to meet the four pillars mentioned above, products can be found from different brands according to the region, that is, after a study of the needs of each region of the country, this division was made into four brands that serve the South region, Southeast, Center-North and Northeast.

The products are then differentiated from the needs of the regions as shown above and within each region it is divided into the types that are studied in this report, Type I, Type II, Type III and Type IV. What differs from them is where they will be applied and the raw materials.

The company's production line has its own limestone extraction mine, which is transported by cable car to the factory, after crushing to result in smaller stones, the limestone is mixed with clay and iron ore in mills until form a kind of flour, which is called Raw Flour, as soon as the flour is mixed, it is stored in silos, after the flour is taken mechanically to the oven, in the oven it will turn into Clinker, which is the cement base, called of "pure cement", (the kiln uses petroleum coke), after leaving the kiln the clinker is cooled and stored in silos until it is milled to be mixed with plaster, slag and pozzolan depending on what type of cement will be produced. So, you have the final product, which is stored and either goes to bagging or silos (in bulk sale) until it is transported to customers.

This project seeks to maximize profit from the production of 4 different cement models. For that, the following data were collected for the construction of the mathematical model:

• Sales: The expected market demand is 2200 tons with a 10% margin of error. In addition, there is a minimum demand of 200 tons for each product.

• Purchasing: Each type of cement consumes different amounts of limestone, iron ore, clay and plaster. Fixed quantities of raw material are purchased on a contractual basis.

• HR: How many people are used to produce per ton of each product/month, since some products go through different processes for their specific characterization. The production line has about 50 operators who can manufacture any of the four products.

• Production: What is the production time (bottleneck machine) to produce the ton of each type of product. They are produced in 2 shifts of 8h each considering 20 consecutive days in the month (totaling 320h/month of production).

• Logistics: How much does all internal logistics and packaging cost to produce each type of cement/ton. The company's goal is to spend less than R $ 250,000.00.

Table 1 below represents the demand forecast with an error of 10% (in tons), the quantity used of each raw material (in tons), the consumption of labor (workers) per product, the time required for production (in hours), the logistical cost of each cement (in reais), as well as the unit profit obtained from the production of each model.

Table 1: Data Collection.

	Ciment 1	Ciment 2	Ciment 3	Ciment 4	Limits
Total demand	1	1	1	1	1980<x<2420
Amount of Limestone	1,8	2,3	2,7	4	5250
Amount of Iron	1	2	2,5	3	4080
Amount of Clay	0,9	0,3	0,1	0,5	1150
Amount of Plaster	1	0,8	5	0,5	1652
Workforce	0,018	0,023	0,027	0,03	50
Production Time	0,1	0,2	0,16	0,14	320
Logistic Coast	100	115	140	130	250000
Profit	1400	2300	3000	4000	Max

Source: Authors, (2020).

III.1 MATHEMATICAL MODEL

Next, the declarations of the decision variables were made to then enter the model, below the variables, restrictions and mathematical model of the problem are presented.

Variables:

- X1: Type I cement;
- X2: Type II cement;
- X3: Type III cement;
- X4: Type IV cement.

Restrictions:

• RV1: Sales restriction 1, minimum expected total demand;

• RV2: Sales restriction 2, maximum expected total demand;

• RV3: Sales restriction 3, minimum cement demand for all works;

• RV4: Sales restriction 4, minimum demand for cement structural works;

• RV5: Sales restriction 5, minimum demand for cement special works - industrial;

• RV6: Sales restriction 6, minimum demand for cement special works - aggressive means;
• RC1: Restriction of purchases 1, quantity of limestone;
• RC2: Restriction of purchases 2, quantity of iron;
• RC3: Restriction of purchases 3, quantity of clay;
• RC4: Restriction of purchases 4, quantity of plaster;
• RRH1: Restriction of human resources, number of operators;
• RP1: Production restriction, production time;
• RL1: Logistics restriction, internal logistics cost.

Linear Programming Model:

The mathematical model is presented below.

Objetive Function:

$$\text{Maximum } f(x) = 1400 * x1 + 2300 * x2 + 3000 * x3 + 4000 * x4 \quad (1)$$

RV1:

$$x1 + x2 + x3 + x4 > 1980 \quad (2)$$

RV2:

$$x1 + x2 + x3 + x4 < 2420 \quad (3)$$

RV3:

$$x1 > 200 \quad (4)$$

RV4:

$$x2 > 200 \quad (5)$$

RV5:

$$x3 > 200 \quad (6)$$

RV6:

$$x4 > 200 \quad (7)$$

RC1:

$$1.8 * x1 + 2.3 * x2 + 2.7 * x3 + 4 * x4 < 5250 \quad (8)$$

RC2:

$$1 * x1 + 2 * x2 + 2.5 * x3 + 3 * x4 < 4080 \quad (9)$$

RC3:

$$0.9 * x1 + 0.3 * x2 + 0.1 * x3 + 0.5 * x4 < 1150 \quad (10)$$

RC4:

$$1 * x1 + 0.8 * x2 + 5 * x3 + 0.5 * x4 < 1652 \quad (11)$$

RRH1:

$$0.018 * x1 + 0.023 * x2 + 0.027 * x3 + 0.03 * x4 < 50 \quad (12)$$

RP1:

$$0.1 * x1 + 0.2 * x2 + 0.16 * x3 + 0.14 * x4 < 320 \quad (13)$$

RL1:

$$100 * x1 + 115 * x2 + 140 * x3 + 130 * x4 < 250{,}000 \quad (14)$$

Non-negative:

$$x1, x2, x3, x4 > 0 \quad (15)$$

IV. RESULTS

In order to achieve the result of the model above, restrictions were inserted in Excel, so that with the help of the Solver supplement, it was possible to find the optimal solution, in order to maximize the company's profit. Table 2 below shows the output results of the decision variables and the maximum profit obtained:

Table 2: Optimized production result.

Product	**Tons**
Ciment I	584
Ciment II	460
Ciment III	464
Ciment IV	472
Max Profit/Month	**R$ 5.155.600,00**

Source: Authors, (2020).

Therefore, the best solution found for the company's production mix is to produce 584 tons of Type I cement, 460 tons of Type II cement, 464 tons of Type III cement and finally 472 tons of Type IV cement - aggressive media. Despite a certain variance, it is possible to see that this optimized solution also resulted in a level production between the 4 products, which distributes resources efforts more evenly and makes it possible to satisfy a larger portfolio of customers, helping the company in general.

In addition, it was possible to carry out an analysis of the restrictions to understand which ones would be used to their limits and which ones would have clearances. This is shown below in Table 3.

Table 3: Analysis of excess resources.

Restriction	**Limits**	**Quantity Used**	**Leftover resources**	**% Leftover**
RV1 and RV2	1980<x<2420	1980	-	-
RC1	5250	5250	0	0%
RC2	4080	4080	0	0%
RC3	1150	946	204	18%
RC4	1652	1652	0	0%
RRH1	50	43	7	14%
RP1	320	290.72	29.28	9%
RL1	250	237.62	12.38	5%

Source: Authors, (2020).

It is possible to observe with the figure above that the restrictions that are not being fully used to maximize the company's profit are those of purchases in the amount of clay (18%), human resources in the number of operators required in the production line (14%), the time required for production (9%) and the costs of internal logistics and packaging for the production of each type of cement (5%). With this it is possible to take actions to reallocate these resources to other areas (such as operators) or to cut inventory expenses, as in the case of clay, which is provided for in the optimized system, which accounts for over 18% of the total purchased, and thus obtain the same revenue with less resources and even cut expenses that can decrease the expenses of the production line.

On the other hand, it is also possible to increase the resources that are being used in their entirety, since there is expected demand for more products and the bottleneck is the internal resources fully used. For this, the quantities purchased of limestone, iron ore and plaster would have to be increased in order to increase production and, consequently, turnover in

search of a greater profit. In this context, a sensitivity analysis was carried out to understand the change in total profit by increasing these resource bottlenecks to enable increased production in an optimized system.

IV.1 SENSITIVITY ANALYSIS

The sensitivity analysis seeks to determine the effect of the variation of a given resource on the total objective value, which in this study is the company's profit. It is a very useful tool in different areas to determine the importance of increasing or decreasing resources and obtaining results even better than the current state. Therefore, a Dual sensitivity analysis was performed so that it was possible to perceive the variation that the objective function would undergo in the variation of the limits of the restrictions. The result of the sensitivity analysis is shown below in Table 4.

Table 4: Sensitivity analysis.

Resource Restriction	Value of restriction	Maximum amount of increment for changing the bottleneck resource	Profit variation with unit increment of resource
RC1 (Limestone)	5250	130	R$ 706,67
RC2 (Iron)	4080	223.1707	R$ 642,67
RC4 (Plaster)	1652	65	R$ 480,00

Source: Authors, (2020).

Table 4 indicates that by increasing 1 ton (unit increment) the quantities of either limestone, or iron ore or plaster, would have an increase in profit of R$ 706.67, R$ 642.67 and R$ 480 respectively. This analysis becomes an important tool for the purchasing manager to see if it is feasible and desirable to increase these resources to increase cement production, since if the cost of a ton of these resources is less than the profit obtained, it would be interesting to implementation of larger purchases. In addition, the increase can be made up to the maximum number of increments indicated in Table 4 before there is a change in the bottleneck resource scenario, where a new sensitivity analysis must be made to understand what the current bottleneck resources are and thus make continuous improvements.

V. CONCLUSIONS

In this work it was possible to present a real case of the application of operational research for decision making with the aid of linear programming, with the main objective of maximizing profits and showing a quantified direction to reduce waste and bottlenecks. Thus, making it possible to provide the company with a tool that enhances its contribution margin, optimizing its product mix.

In addition, with the sensitivity analysis, it was evident that the company has significant leftover raw materials, number of operators, production time and the cost of internal logistics. With this type of leveling proposed, the company will be able to eliminate excessive variability in production, making it more repetitive and predictable. With this, it will make it possible to identify the quantities of raw materials and finished products that are really necessary to keep in stock, which makes it possible to reduce the number of items stocked, increasing the flexibility of response to the customer and making production closer to real demand, with a constant pace and following quality standards. In this way, the company will be able to dimension its resources better, becoming more competitive.

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RESEARCH ARTICLE OPEN ACCESS

PROPOSAL OF COMPUTATIONAL TOOL DO SUPPORT MAINTENANCE DECISION FOR ELECTRIC POWER GRIDS

Marcelo Carlos Afonso Carvalho[1], Matheus Coutinho Cunha[2], Igor Assumpção Melo[3], Márcio Zamboti Fortes*[4], Angelo Cesar Colombini[5] and Vitor Hugo Ferreira[6]

[1, 2, 3, 4, 5, 6] Federal Fluminense University - UFF. Niterói–Rio de Janeiro, Brazil.

[4]http://orcid.org/0000-0003-4040-8126, [5]http://orcid.org/0000-0002-8906-4128

Email: *mzamboti@id.uff.br

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ABSTRACT

The Equivalent duration of electric power service interruptions per customer unit (DEC) and the Equivalent frequency of electric power service interruptions per customer unit (FEC) are determinant indexes for the application of penalties by the National Agency for Electrical Power (ANEEL) of Brazil over concessionary companies. Established by ANEEL's 'Procedures for Electrical Power Distribution on the National Electrical System' (PRODIST Module 8), these indexes indicate the continuity of services, consequently the quality of services, must be kept low, therefore methodologies capable to support company´s decisions for cost reduction of operations and penalties by underperformance are always wanted. This analysis of power grids' failures and repair operations uses information about the electrical distribution of the State of Rio de Janeiro converted into data that includes costs and other details surrounding maintenance operations. The objective is to compute and to find the optimum allocation of resources to attenuate most of the impact of power outages. The discrepancies found along the development of this work had to be controlled by averages, standard deviations and the estimation of uncertainties. The steps were established targeting cost reductions opportunities, based on the several documents such as reports provided to ANEEL by the concessionary company responsible for the power distribution for the City of Rio de Janeiro; the PRODIST Module 8; weather data for the areas where the power grids are located; and the month of the year and number of typical occurrences. The conclusions are limited by the choices of computational methods applied, the quality of the information acquired, and by the efforts spent to adjust and reorganize all the information into data.

I. INTRODUCTION

Between the standard parameters [1] used to measure the power quality in Brazil special attention is given to the continuity of the services for the distribution of electric power which, by means of collective continuity indexes for the period of time and frequency of the electrical distribution interruptions, allows the National Agency of Electrical Power (ANEEL) to monitor, evaluate and control the performance of the concessionary companies responsible for the power distribution.

These interruptions are classified and calculated [2]; and the two initial classes are titled Short Duration Voltage Variation (VTCD), for variations with the duration from one (1) second to less than three (3) minutes; and up to the time needed for emergency occurrences that take more than three minutes. In both cases, there are financial compensations to be paid by the concessionaries of power distribution services.

Between the faults that generate financial compensations were highlighted the interruptions and individual occurrence frequency by consumer unit respectively: DIC, established by the interval time of de occurrence; FIC, the repetition frequency; DMIC, the maximum duration time of the continuous interruption by consumer unit (or connection point); and DICRI, the violation of the limit of individual continuity with reference to a Critical Day per consumer unit or connection point.

The financial compensations are paid by the monetary reference value EUSD, which corresponds to the value of charges for the use of the system of power distribution by the reference

month of the latest measurement, whenever a violation of the individual index limit for the DIC, FIC and DMIC happens, in relation to the monthly, trimestral or annual period calculation.

For the violations of the individual continuity limit of the index DICRI, the concessionary must compensate consumers and power generation central plants with access to the system distribution, including the ones connected to the transmission grid owners of Other Transmission Installations (DIT), providing credit in bills to be paid up to two months after the accrued period.

The concern with power quality indexes is worldwide, and is demonstrated in many correlated researches; between them is plausible to quote the following works: "Condition monitoring techniques and diagnostic test for lifetime estimation of power transformers avoiding failure/faults that can cause blackout and not energy supplied to consumers" [3], "Maintenance management systems focused in availability" [4], "Impact of new generation sources (in special mini/micro distributed generation) within the distribution network" [5, 6].

The financial impact of fail events without de correct planning are solved during emergencies; these cases are converted into data analyzed for the creation of computational prevision and estimate price for the network repairs and maintenance actions - targeting future cost reductions. Based on the history and registry of previous "repairs on demand", considering the condition of the distribution network, extrapolations are made in order to anticipate future actions for the financial cost reductions for problems caused by interruptions and variations at the consumers units integrated into the collective (DEC); and to reduce the frequency of the interruptions integrated into (FEC) that have equivalent names (SAIDI) - System Average Interruption Duration Index, and (SAIFI) - System Average Interruption Frequency Index, as established by the U.S. Department of Energy regulation [7]. There are other researches focused in the duration of the financial impact, e.g. the correct localization of the knowledge basis, such as related on [8]; or in mathematical tools to construct the problem model [9]. The paper structure will be as follows: section II describes the database; section III depicts the Auxiliary Tables; section IV describes the Automatic Classification used for the project, section V introduces the WEKA explorer, and section VI presents the conclusion. By the end is presented the work acknowledgements and references.

II. DATABASE

To use of the information obtained from a concessionary's reports to build the CSV-Excel tabled plan "PREVDEC_INTERRUPTIONS" for the years 2014, 2015, 2016, 2017 and 2018, it was necessary to correct, from the original table, attributes unfit to the analysis, which means, it was necessary to classify and treat the initial information into a database.

After the classification, the archive received eleven new attributes that included data of the weather conditions at the State of Rio the Janeiro during the days and hours of the maintenance occurrences; and economic data about the population surrounding the network who lives "below normal conditions" according to the classification and database provided by the Brazilian Institute of Geographical Statistic (IBGE), 2010, the latest available.

The information was combined in a CSV file with 52173979 bytes. The final file included the field PROD_QS_MD, the product of the attributes QTY_CONS and MIN_DURATION; and the attribute MONTH, extracted from the date of the occurrences of the fail/interruption of the distribution network because the final planning for the intervention must be monthly; the weather conditions; and seasonality of social/economical problem, such as unemployment after relevant commercial-calendar dates and the end of employment contracts, which may influence the consumer characteristics affecting the distribution network problems indexes, which would make more complex the classification and analysis method of cluster and final grouping. After this change to the database were removed multi-valued fields resulting on a final plan-table with 36 attributes in a 36292Kbytes file. The Table 1 presents the list of attributes used for classification.

Table 1: PREVDEC_INTERRUPTIONS_2017.CSV DATA.

Nº	Data structure, CSV format	
	Attribute	***Description***
01	DATE_REF	Year and month of the occurrence
02	NUM_DOCUMENTO	Document number
03	NUM_ID_INTERRUPCAO	Interruption number
04	NUM_ID_ITEM	Sequential number of the affected area
05	COD_CONJUNTO	Set number
06	COD_CONJUNTO_ANEEL	Set code number
07	DES_CONJUNTO	Set description
08	NUM_ID_HIERARQUIA	Hierarchic position number
09	COD_HIERARQ	Hierarchic code
10	COD_SIGLA	Acronym code of parts of the system
11	DES_HIERARQ	Neighborhood description
12	NUM_ID_MUNICIPIO	City Code
13	NOM_MUNICIPIO	City Name
14	COD_TIPO_DISP_OPER	Controlled device type code
15	COD_EQUIP_OPER	Controlled equipment code
16	DES_EQUIP	Controlled equipment description
17	DES_LABEL_DISP_OPER	Controlled device draw label
18	DES_LABEL_SUBEST	Substation draw label
19	DES_LABEL_ALIMENT	Feeder draw label
20	DES_COMPL_LABEL_ALIMENT	Feeder complementary draw label
21	QTD_CONS	Consumers quantity
22	MIN_DURACAO	Interruption interval in minutes
23	DAT_INICIO	Beginning of occurrence date in format: 'YYYY/MM/DD HH:MM:SS'
24	DAT_TERMINO	End of occurrence date in format: 'DD/MM/YYYY HH:MM:SS'
25	DAT_TERMINO_CORR	Fixed 'End of occurrence date' in format: 'DD/MM/YYYY HH:MM:SS'
26	TAG_PROG_ACID	????
27	NUM_IDT_GRUPO_CAUSAS	Group of causes identification number
28	NUM_IDT_CAUSA_INTERRUPCAO	Interruption cause identification number
29	DESC_CAUSA	Cause description
30	COD_TIP_EXPURGO	Exception type code
31	DES_TIP_EXPURGO	Exception type description

Source: Authors, (2020).

By treating the attributes was obtained a CSV file and an automatic class sequencer program. The automatic class sequencer program was developed for this work to generate the auxiliary tables and its foreign keys codified (COD_) for the alphanumeric attributes in CSV format; simultaneously generated corresponding ARFF files, ready to be used with the WEKA program [10]. WEKA has in numerous applications and is known by academics, having many publications such as described in [11-13]. The development is the result of research to the literature included in the software packages MSVB, VB3, VB4, VB5, VB6 and MSDN between others.

III. AUXILIARY TABLES

The following auxiliary tables were created (Tables 2 to 16) for this work and the identified classes substituted at the main table

by its equivalent code, reducing the total size of the file and the computational weight for processing the different analysis methods for data correlation. Unidentified objects were substituted by the symbol (?), the ARFF notation for unidentified elements; and the attribute. DES_CONJUNTO was dismembered in two fields, DES_CONJUNTO and TIP_DES_CONJUNTO; due to the size of the tables, some are presented only with few lines.

III.1 DES_CONJUNTO

It was divided into 107 classes in two separated attributes, COD_CONJUNTO and DES_CONJUNTO - Table 2.

Table 2: COD_CONJUNTO.

Nº	Data structure, CSV format	
	Attribute	***Description***
01	COD_CONJUNTO	DES_CONJUNTO
02	D001	AREIA_BRANCA_AEREO
03	D002	COELHO_DA_ROCHA
04	D003	MENA_BARRETO_AEREO
05	D004	CAMARI
- - -	- - -	- - -
105	D104	BOTAFOGO_AEREO_URBANO
106	D105	BARRA_2
107	D106	SANTO_ANTONIO_AEREO_URBANO
108	D107	CAMERINO_SUBTERRANEO

Source: Authors, (2020).

III.2 TIPO_DES_CONJUNTO

It was divided into 6 classes in two separated attributes, COD_TIP_DES_CONJUNTO and TIPO_DES_CONJUNTO - Table 3.

Table 3: COD_TIPO_DES_CONJUNTO.

Nº	Data structure, CSV format	
	Attribute	***Description***
01	COD_ TIPO_DES_CONJUNTO	TIPO_DES_CONJUNTO
02	T1	AEREO
03	T2	?
04	T3	AEREO_URBANO
05	T4	AEREO_MT/MT
06	T5	AEREO_AT/MT
07	T6	SUBTERRANEO

Source: Authors, (2020).

III.3 DESC_SIGLA

It was divided into 10 classes in two separated attributes, COD_SIGLA and DESC_SIGLA - Table 4.

Table 4: COD_DESC_SIGLA.

Nº	Data structure, CSV format	
	Attribute	***Description***
01	COD_SIGLA	DESC_SIGLA
02	S01	BX/NI
03	S02	CS/CE
04	S03	VP/TR
05	S04	OE/JP
06	S05	LE/PE
07	S06	CS/BA
08	S07	VP/VR
09	S08	BX/CX
10	S09	LE/ME
11	S10	OE/CG

Source: Authors, (2020).

III.4 DESC_ HIERARQ

It was divided into 91 classes in two separated attributes, COD_DES_HIERARQ and DES_HIERARQ – Table 5.

Table 5: COD_DES_HIERARQ.

Nº	Data structure, CSV format	
	Attribute	***Description***
01	COD_DES_HIERARQ	DES_HIERARQ
02	H01	BELFORD_ROXO
03	H02	MESQUITA
04	H03	VILA_DE_CAVA
05	H04	CENTRO
- - -	- - -	- - -
89	H88	MATOSO
90	H89	PAES_LEME
91	H90	SIMAO_PEREIRA
92	H91	SANTANA_DESERTO

Source: Authors, (2020).

III.5 COD_MUNICIPIO

It was divided into 36 classes in two separated attributes, COD_MUNICIPIO and NOME_MUNICIPIO - Table 6.

Table 6: COD_ MUNICIPIO.

Nº	Data structure, CSV format	
	Attribute	***Description***
01	COD_MUNICIPIO	NOM_MUNICIPIO
02	M01	BELFORD_ROXO
03	M02	MESQUITA
04	M03	NOVA_IGUACU
05	M04	RIO_DE_JANEIRO
- - -	- - -	- - -
36	M35	SIMAO_PEREIRA(MG)
37	M36	SANTANA_DO_DESERTO(MG)

Source: Authors, (2020).

III.6 COD_EQUIP

It was divided into 37 classes in two separated attributes, COD_EQUIP and DES_EQUIP - Table 7.

Table 7: COD_EQUIP.

Nº	Data structure, CSV format	
	Attribute	***Description***
01	COD_MUNICIPIO	NOM_MUNICIPIO
02	E01	DISJUNTOR
03	E02	RAMAL
04	E03	CHAVE_FUSÍVEL_MT_DERIVAÇÃO
- - -	- - -	- - -
37	E36	AUTO_TRANSFORMADOR_MT
38	E37	CHAVE_SECCIONADORA_MT_SF6_C.R.

Source: Authors, (2020).

III.7 DES_LABEL_DISP_OPER

The classification of the attribute resulted in 153.510 values for the 262.763 instances; this result served the purpose of eliminating the attribute due to its large dispersion and lack of convergence. It is presented in a resumed form at Table 8.

Table 8: COD_DLD_OPER.

Nº	Data structure, CSV format	
	Attribute	***Description***
01	COD_DLD_OPER	DES_LABEL_DISP_OPER
02	DO000001	ABRDJ3781
03	DO000002	412973612
04	DO000003	CF-857811
05	DO000004	412041659
- - -	- - -	- - -
153508	DO153507	420984907
153509	DO153508	411151989
153510	DO153509	413462798

Nº	Data structure, CSV format	
	Attribute	*Description*
153511	DO153510	410709003

Source: Authors, (2020).

III.8 DES_LABEL_SUBEST

It was divided into 391 classes in two separated attributes, COD_SUBEST and DES_LABEL_SUBEST - Table 9.

Table 9: COD_SUBEST.

Nº	Data structure, CSV format	
	Attribute	*Description*
01	COD_SUBEST	DES_LABEL_SUBEST
02	S001	ABR
03	S002	MNB
04	S003	CRM
05	S004	CMR
- - -	- - -	- - -
389	S388	JDB_Null
390	S389	SAT_SAT
391	S390	ETV_ETV
392	S391	SRD_ESP

Source: Authors, (2020).

III.9 DES_LABEL_ALIMENT

It was divided into 3862 classes in two separated attributes, COD_DES_ALIMENT and DES_LABEL_ALIMENT - Table 10.

Table 10: COD_DES_ALIMENT.

Nº	Data structure, CSV format	
	Attribute	*Description*
01	COD_DES_ALIMENT	DES_LABEL_ALIMENT
02	A0001	[ABR_010]
03	A0002	[MNB_001]
04	A0003	[CRM_0007]
05	A0004	[CMR_33090]
- - -	- - -	- - -
3860	A3859	LDA_PENNA
3861	A3860	LDS_30560
3862	A3861	LDS_24163
3863	A3862	LDS_1960

Source: Authors, (2020).

III.10 COD_CL_ALIMEN

It was divided into 3911classes in two separated attributes, COD_CL_ALIMENT and DES_COMPL_LABEL_ALIMEN - Table 11.

Table 11: DES_COMPL_LABEL_ALIMEN.

Nº	Data structure, CSV format	
	Attribute	*Description*
01	COD_CL_ALIMENT	DES_COMPL_LABEL_ALIMEN
02	DA0001	LDA AUREA
03	DA0002	LDA SALUSSE
04	DA0003	LDA PARIS
05	DA0004	LDS 33090/LDA SILVINO
- - -	- - -	- - -
3909	DA3908	[ETV] LDA PENNA
3910	DA3909	[BRR] LDS 30560
3911	DA3910	[SAT] LDS 24163
3912	DA3911	[SAT] LDS 1960

Source: Authors, (2020).

III.11 ATRIBUTO DESC_CAUSA

It was divided into 99 classes in two separated attributes, COD_CAUSA and DESC_CAUSA - Table 12.

Table 12: ATRIBUTO DESC_CAUSA.

Nº	Data structure, CSV format	
	Attribute	*Description*
01	COD_CAUSA	DESC_CAUSA
02	C01	FALHAS_EM_EQUIPAMENTOS-REDE_DE_MT_PARTIDA_0U_MAU_ESTADO
03	C02	FALHAS_EM_EQUIPAMENTOS-RAMAL_AEREO
04	C03	FALHAS_EM_EQUIPAMENTOS-CHAVE_FUSIVEL
05	C04	FALHAS_EM_EQUIPAMENTOS-ESTAI
- - -	- - -	- - -
97	C96	PROGRAMADA-ENTREGA_DE_OBRAS
98	C97	PROGRAMADA-OBRA_CIVIL
99	C98	PROGRAMADA-OUTRAS_DISTRIBUIDORAS
100	C99	GERACAO-NAO_PROGRAMADO

Source: Authors, (2020).

III.12 COD_CL_ALIMENT

It was divided into 3911 classes in two separated attributes, COD_CL_ALIMENT and DES_COMPL_LABEL_ALIMEN - Table 13.

Table 13: COD_CL_ALIMENT.

Nº	Data structure, CSV format	
	Attribute	*Description*
01	COD_CL_ALIMENT	DES_COMPL_LABEL_ALIMEN
02	DA0001	LDA AUREA
03	DA0002	LDA SALUSSE
04	DA0003	LDA PARIS
05	DA0004	LDS 33090/LDA SILVINO
- - -	- - -	- - -
3909	DA3908	[ETV] LDA PENNA
3910	DA3909	[BRR] LDS 30560
3911	DA3910	[SAT] LDS 24163
3912	DA3911	[SAT] LDS 1960

Source: Authors, (2020).

III.13 COD_EXPURGO

It was divided into 4 classes with two separated attributes, COD_EXPURGO and DES_TIP_EXPURGO - Table 14.

Table 14: COD_ EXPURGO.

Nº	Data structure, CSV format	
	Attribute	*Description*
01	COD_EXPURGO	DES_TIP_EXPURGO
02	X1	SEM_EXPURGO
03	X2	DIA_CRITICO-ACIDENTAL
04	X3	SITUACAO_DE_EMERGENCIA
05	X4	DIA_CRITICO-PROGRAMADA

Source: Authors, (2020).

The weather information of the City of Rio de Janeiro between the days of January 1st, 2017 to October 31, 2019 were obtained from the Internet site timeanddate.com, converted and organized in the format CSV and ARFF. The final file with 4137 instances and thirteen (13) attributes refers to the daily weather registers collected in interval of six (6) hours. Table 15 (CLIMA E TEMPO-RJ) presents the following attributes for the analysis.

Table 15: CLIMA E TEMPO – RJ.

Nº	Data structure, CSV format	
	Attribute	***Description***
01	HORA_S	Hour of registration of the weather data
02	DIA_S	Week day of registration of the weather data
03	DIA_N	Day of registration of the weather data
04	ANO_MES	Year and Month composition of the registration of the weather data to the format YYYYMM
05	HORA_I	Initial time of the weather data registration
06	HORA_F	End time of the weather data registration
Registry for a specific year, month and day between the time interval HORA_I and HORA_F		
07	TEMP_MAX	Maximum Temperature, ºC
08	TEMP_MIN	Minimum Temperature, ºC
09	PRESS	Atmospheric Pressure, mbar
10	VENTO	Wind velocity in km/h
11	HUMID	Relative Humidity (%)
12	ANO_MES_DIA	Converted Data to the format ISO 8601 YYYYMMAA
13	DESC_TEMP	Qualified description of the weather conditions

Source: Authors, (2020).

For the association of the table with the classified attribute DESC_TEMP with 34 values for the descriptions of the weather condition was used the resumed organization show on Table 16.

Table 16: DESC_CLIMA.

Nº	Data structure, CSV format	
	Attribute	***Description***
01	COD_CLIMA	DESC_CLIMA
02	CL01	SUNNY
03	CL02	SCATTERED_CLOUDS
04	CL03	THUNDERSTORMS_OVERCAST
…	…	…
32	CL31	SCATTERED_SHOWERS_MOSTLY_CLOUDY
33	CL32	THUNDERSTORMS_FOG
34	CL33	DRIZZLE_MOSTLY_CLOUDY

Source: Authors, (2020).

IV. AUTOMATIC CLASSIFICATION

The following steps were necessary for the creation of an automatic classification system:

- To initialize the VBA-Excel program [10]
- To make subroutines in VBA-Excel
- Function Open CSV to get the CSV data
- Function classification to start the process
- Function Classification filter for the automation
- To evaluate the input data.

Analyzing the Figure 1 is possible to observe that most fails occurred at weather conditions between 25ºC to 29ºC.

Interruption frequency by month Graphic (2017).

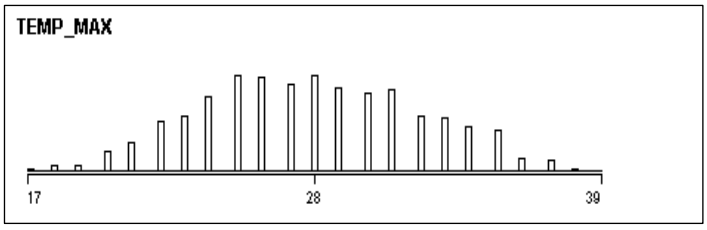

Figure 1: Maximum Temperature (ºC) and fails per month (2017).
Source: Authors, (2020).

V. WEKA EXPLORER

VBA EXCEL resources combined to Weka [11-14] were used for the generation of the following graphics and tables. The software provides a learning environment combined with knowledge, such as the name behind acronym suggests, allowing studies and the development of algorithm for future projections, in this case, the ideal planned actions to reduce DEC and FEC by means of the innumerous machine learning resources available at the virtual workbench where it is allowed to visualize data during analysis for the construction of the primitive model. At this section are presented correlations and analyzed the problem's data nature that was classified by means of VBA Excel.

Figure 2 shows one of the desired configuration screens for the software output.

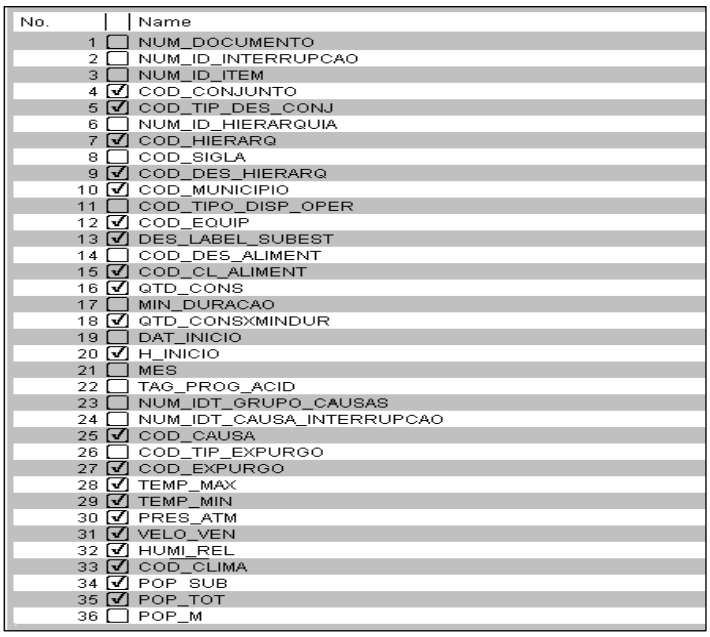

Figure 2: WEKA EXPLORER – Configuration.
Source: Authors, (2020).

The following examples show the output for the developed software from the use of data classification (Figures 3 to 6).

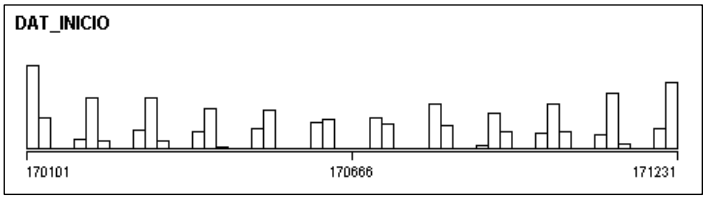

Figure 3: Graphic of the Interruption frequency during one year by month.
Source: Authors, (2020).

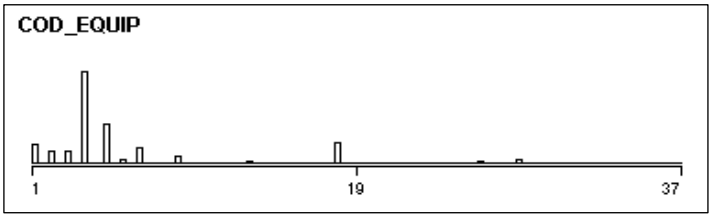

Figure 4: Graphic of the Interruption frequency during by equipment based on Table 7.
Source: Authors, (2020).

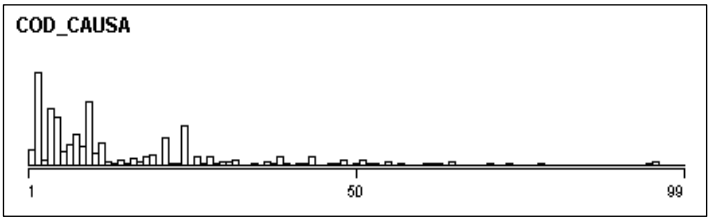

Figure 5: Graphic of the Fault frequency.
Source: Authors, (2020).

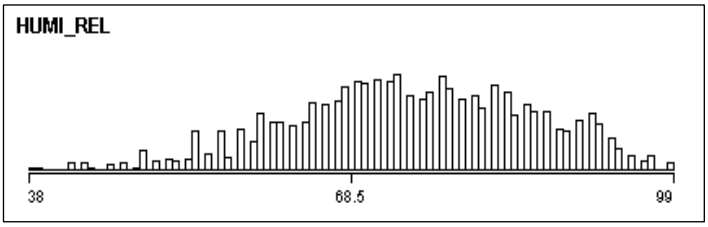

Figure 6: Graphic of the Relative humidity % during the period of analysis.
Source: Authors, (2020).

Another possible application for the software it´s to cross analysis between the weather conditions (e.g. atmospheric pressure) versus the causes of problems from the maintenance data table, which showed that for pressures near 1032 mbar there was a larger frequency of fails registered for the year 2017.

With the classification of the occurrence dataset per month, there is the confirmation of a bigger index of failures during the summer vacation (January) and by the end of the semester (from October to December), as showed by Figure 7 - Interruption frequency by month Graphic (2017) (axel x, H_INICIO, axel y, MES).

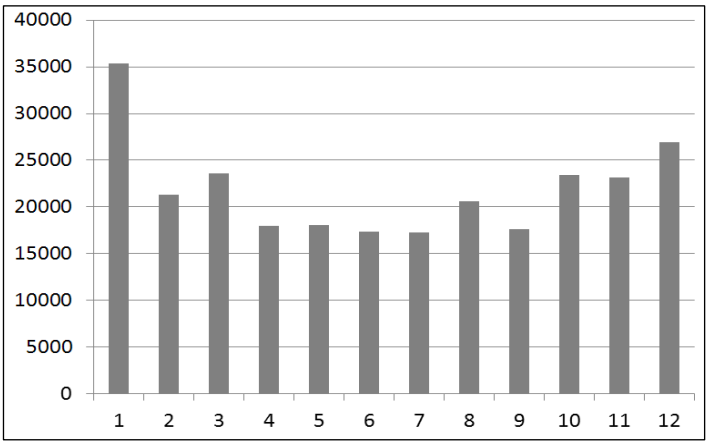

Figure 7: Graphic of the Relative humidity % during the period of analysis.
Source: Authors, (2020).

VI. CONCLUSIONS

Although many resources were used, after the analysis of the occurrence patterns it was not possible to find correlations to indicate a unique path to the machine learning for projections of strategic plans to apply for the power network maintenance. However, for the present study was available only the data of 2017; considering the seasonal aspects of maintenance, it is proposed to extend the evaluation to include the years 2018 and 2019, nevertheless the tool proved useful for the analysis of the databank and may indicate paths for the maintenance teams to act targeting planning the reduction of indicators that have direct impact over power quality. The individual analysis pointed to areas that should receive more attention considering that they concentrated the problems correlated to major fails cases, and basing on the study of the databank were found, respectively from the most severe to the lower frequency the following items:

- Equipment faults – Aerial power lines
- Equipment faults – Connections and equipment anchorage
- Environment – Tree branches and falling trees
- Third part action – Public service companies or its contractors and undetermined reasons – After power network inspection
- Equipment faults – Broken power network's BT or in bad conservation conditions, transformers, and Broken power network's MT or in bad conservation conditions
- Third part action – Objects over the power network
- Natural phenomena - Storms

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RESEARCH ARTICLE OPEN ACCESS

REVERSE POST-CONSUMPTION CYCLE FOR A PAPER ITEMS MANUFACTURING INDUSTRY

Dayvid Viéga da Silva e Silva[1], Douglas Vieira Barboza[2] and Marcelo Jasmim Meiriño[3]

[1] Higher Institute of Management - ISG. Lisbon, Portugal.
[2, 3] Federal University of Fluminense - UFF. Niterói–Rio de Janeiro, Brazil.

[2]http://orcid.org/0000-0002-2653-8541, [3]http://orcid.org/0000-0001-9165-2300

Email: dayvid_sv@hotmail.com, douglas.barboza@id.uff.br, marcelojm@id.uff.br

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Reverse logistics,
Sustainability,
Recycling,
Reverse.

ABSTRACT

The growth in competitiveness, the relentless search for cost minimization, the reduction of environmental impact, sustainability and compliance with laws, have leveraged studies on the potential of Reverse Logistics when implemented in the most diverse means of the industry to explore its benefits. Therefore, this research aims to demonstrate how the implementation of reverse logistics can establish ways of adapting to the new needs of the industry, enhancing its gains, visibility and productive growth within an industry producing school and office supplies. To this end, a qualitative research was carried out based on technical visits and interviews with professionals in management positions at the company. During the development process, reverse logistics techniques were also used, such as product life cycle assessment. In addition to contributing to the development of the literature on reverse logistics, this work brings positive results to all links involved in the system.

I. INTRODUCTION

In view of the worsening of environmental issues, there are many initiatives that can be taken by companies that commonly contribute to certain damages to occur. Parts of the mitigation actions may come from logistics, either in their usual flow or through the reverse flow.

It is known that logistics has the function of creating and maintaining processes for the storage and distribution of internal and external raw materials and products, and one of its important areas is reverse logistics, which involves all operations related to the reuse of products and materials, in the search for a reintegration of these to sustainable productive processes, therefore being an instrument of economic and social development, aiming at the reuse of industrial residues for their reintroduction in the productive cycle that revalues a product or material, still preventing residues from being thrown directly into nature [1].

Regarding the available literature, the expressive informative content on reverse logistics is perceived, however few address the application of this method to the industry of the manufacture of articles of the paper industry. Thus, the motivation for this research came from the need to propose measures that improve the service to consumers of these products, reduce the generation of waste, minimizing the use of water and raw materials, improve financial income, maintaining the quality of their products and meet the requirements of the law.

Methodologically, the present study was developed from a case study in an industry producing school and office supplies, consisting essentially of paper, located in Itaboraí in the State of Rio de Janeiro, carried out by consulting documents of private ownership company, interviews with managers, technical visits to the site to recognize their production and develop a strategy for applying the reverse post-consumption cycle.

In this way, the present research aimed to demonstrate how reverse logistics can establish ways of adapting to the new needs of the industry, enhancing its gains, visibility and productive growth within an industry that produces paper goods.

In the structural aspect, the article is divided into five parts: in a first, contextualization and the final objectives of the approach proposed in this study are exposed. In a second part, the main characteristics of reverse logistics are presented, in order to set the stage for the development of a strategy for the application of this area of logistics to the chosen case. In a third part, the

environmental concern and public policies related to the reduction of solid waste are addressed. The fifth part provides an understanding of the methodology used in the analysis of the enterprise where the study was carried out, as well as an exhibition of characteristics, the examination and documentation of the application of the method for industry, which translate the main results of the research. And in a fifth and final phase, the achievement of the goals pursued in the objective of the study is concluded.

II. REVERSE LOGISTICS

Solid waste (commercial, industrial, domestic, hospital) is a serious environmental, social and economic problem for today's society. And reverse logistics is one of the possible solutions to mitigate it, and strategies like this are increasingly desirable, since it is practically impossible to give an adequate end to all the waste that we generate daily [2].

Actions involving a given cycle that includes the final disposal of a product are treated by the field of study of Reverse Logistics, provided by the Reverse Logistics Executive Council - RLEC, as being the process of planning, implementing and controlling the flow of raw materials, work in process and finished product (and its information flow) from the point of consumption to the origin in order to recapture value or offer an ecologically appropriate destination [3].

Direct logistics operates in the flow of materials, services and information, from generation to consumption. However, reverse logistics is concerned with reversing such flows from consumption to origin, adding values and creating more suitable destinations, so this technique has increasing visibility and space. [4].

The reverse distribution channels are made up of two distribution categories, defined as post-consumption and after-sale, the first category of which occurs when goods, with little or no use, return to the different links in the direct distribution chain for various commercial reasons, for example: error when ordering, exchange for warranty, manufacturing or operating defects, or even for damage caused during transportation. While the reverse distribution channels of post-consumption are constituted by the reverse flow of products at the end of their useful life, their packaging, as well as industrial waste, which receive different treatment due to its great importance [5].

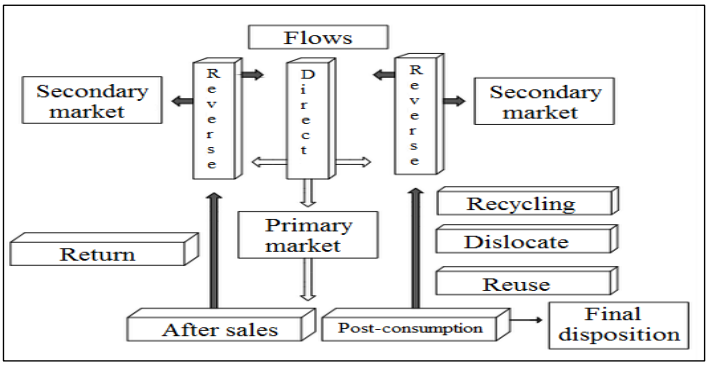

Figure 1: Direct and reverse distribution channels.
Source: [5].

A rational and ecologically correct cycle for waste generated in industries has been one of the goals of companies of this century, due to environmental legislation with strong growth in their restrictions and consumers more aware of the adequate treatment given to industrial waste, companies are being forced to rethink new ways of structuring themselves in the market, focusing on attention to the total life cycle of their products, as well as their final disposition [6].

Only recently has a concern been raised with regard to the reverse distribution channels, their stages, ways and means in which a percentage of these little used products after sale or after the end of their useful life, may return to the production or business cycle, regaining value in different ways, in the same market, in secondary markets, through the reuse of its components or constituent materials [5].

Reserve Logistics can be defined as the process of planning, implementing and controlling the efficiency and cost effective flow of raw materials, in-process inventories, finished products and the corresponding consumption information to the point of origin for the purpose of recapture the value or allocate to the appropriate provision [3]. Considering that logistics is an integrative concept that seeks to develop a vision of the company as a comprehensive system to meet the needs of the market strategically [7].

An important issue is that in recent years, environmental legislation has encouraged several companies to decide to implement Reverse Logistics policies for their products and packaging, because of the need to differentiate between services offered and policies to continuously cut costs [8].

Reverse logistics is a sustainability strategy that companies can use as an economic opportunity for ethical reputation, society and its ties, and can generate more dignified conditions such as better quality of life, employment, income, ethical attitudes, among others. And according to the three areas in the triple botton line concept, economic sustainability combines the preservation of the environment with the financial return, so that it involves the areas of environment (planet), social (people) and economic (profit) [9], which must be seen in an interconnected way in favor of sustainable development, as can be seen in Figure 2.

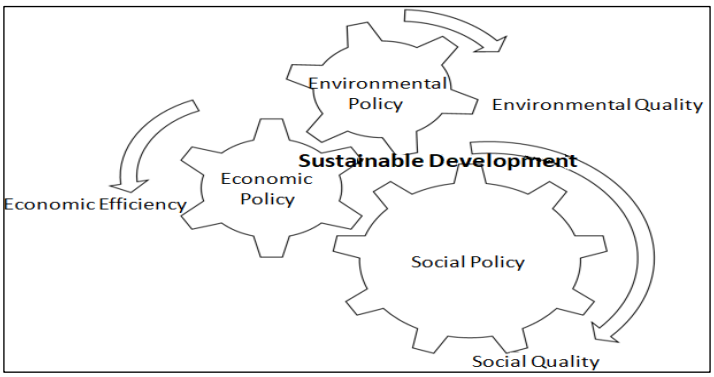

Figure 2: Interconnection of the three dimensions of sustainable development.
Source: [10].

It is important to awaken in the managers of different organizations, the interest so that more and more sustainable actions are incorporated into companies and can influence the community to also adopt such practices, believing daily changes and simple daily actions has this potential [11].

With the intense competitiveness present in the current market, investment in sustainable measures as a differential in the market makes it necessary that, from the beginning of business activities, managers align their processes strategically through process management techniques applied in this sense [12].

III. ENVIRONMENTAL CONCERN AND PUBLIC POLICIES

The worsening of environmental problems appears with greater visibility in a large portion of sectors of the population, especially in developed countries, from the 20th century onwards, being affected by the impacts generated by the industrial revolution [13].

Since then, the environmental issue has been addressed in several conferences and documents, such as the Club of Rome, the Stockholm Conference, the Report "*Our Common Future*", ECO 92, the Kyoto Protocol, among others, in order to seek sustainable guidelines for the environment, which has been influencing the population's behavior [14].

A large portion of the population has been increasingly concerned with the various aspects of ecological balance. According to the author himself, this has been proven through public opinion surveys that reported that the increase in awareness in today's society is true, especially in countries with greater economic development [5].

Based on biological analogies with natural ecosystems, Industrial Ecology identifies and proposes new arrangements for the flow of energy and materials in industrial systems, having as basic principles the search for integration of economic activities and the reduction of environmental degradation [15].

In order to reduce part of the impacts that culminate in an environmental crisis, the National Solid Waste Policy (PNRS) was developed, instituted by Law No. 12,305, of August 2, 2010, and regulated by Decree No. 7,404, of December 23, 2010. And in terms of its principles, the following stand out:

I. protection of public health and environmental quality;

II. non-generation, reduction, reuse, recycling and treatment of solid waste, as well as environmentally appropriate final disposal of waste;

III. encouraging the adoption of sustainable patterns of production and consumption of goods and services;

IV. adoption, development and improvement of clean technologies as a way to minimize environmental impacts;

V. incentive to the recycling industry, with a view to promoting the use of raw materials and inputs derived from recyclable and recycled materials; [...] [16].

The implementation of a National Solid Waste Policy (PNRS) in Brazil is a complex process, as the country has significant continental dimensions. On the other hand, this policy is important to boost and create new opportunities in several areas, in particular reverse logistics [17].

In order for the industries to have greater responsibility in their conduct, there are some laws that restrict certain actions, as is the case of Law No. 9,605, of February 12, 1998 - Providing for the criminal and administrative sanctions derived from conduct and activities harmful to the environment environment, and other measures.

From the crimes against flora in article 46, the previous law deals with receiving or acquiring, for commercial or industrial purposes, wood, firewood, coal and other products of vegetable origin, without requiring the display of the seller's license, granted by the competent authority, and without using the route that should accompany the product until final processing.

Another relevant article is related to pollution and other environmental crimes, when in art. 54 deals with causing pollution of any kind at levels that result or may result in damage to human health, or that cause the death of animals or the significant destruction of flora [18].

IV. CASE STUDY

IV.1 METHODOLOGY

As for the approach, it is stated that this research is characterized as qualitative, that for [19], it is an approach that prioritizes studies where the variables are still unknown, as it is a method in which the quantity is replaced by intensity, through the analysis of different sources that can be crossed.

The technical procedure used in this work was the case study, which is a form of research that seeks to investigate a contemporary phenomenon within its context and a reality, especially when the limits between these are not clearly defined [20].

For this reason, a company was chosen with its business focused on the area of school supplies, being called "PAPER S.A" during this work so that its original name is preserved. It is an industry that uses a large amount of paper in its production as the basis of its products, which is a key component for the creation of this work.

In the search for the solution of these aspects, technical visits were made to the production industry, where a bank of questions was answered by an outstanding professional within the company.

IV.2 PRODUCT LIFE CYCLE

The company uses some materials such as paper, wire, paint and cardboard, the focus of which is on a specific material, which is paper. Made from wood, from which cellulose fibers are extracted, converted into paper after a series of industrial processes.

For each ton of paper that is recycled, 32 pine and 3 eucalyptus trees are saved, having even more benefits when compared to the amount of water used for white and recycled papers, when for the production of 1 ton of recycled paper it is necessary 2 thousand liters of water and for traditional, white, this volume can reach 100 thousand liters [21]. As a result, there is a concern to reduce this use by analyzing the product's life cycle with the implementation of reverse logistics techniques.

The production of the objects generated by this company follows a simple direct flow starting from the arrival of the raw material (see Figure 3), which according to one of the responsible engineers it is estimated that about 80% to 85% of these come from the paper through the reels of white and recycled paper. Currently, the use of white paper rolls is approximately 9 times greater than that of recycled paper.

Figure 3: Paper rolls.
Source: Authors, (2020).

From this stage, the coils are sent to production, where they are ruled, cut paper and covers through specific machinery and join the parts in a manual service. The production sector also has a machine of German origin, called Bielomatik, which eliminates all production processes, as it is a technology that allows the entry of raw material into its initial door and at the end of its delivery cycle. the fully finished product.

After finalizing production and inspecting its quality, the products go to stock, where their destinations for the most diverse customers are managed, for example, the wholesaler and retailer network, according to the supply chain in Figure 4.

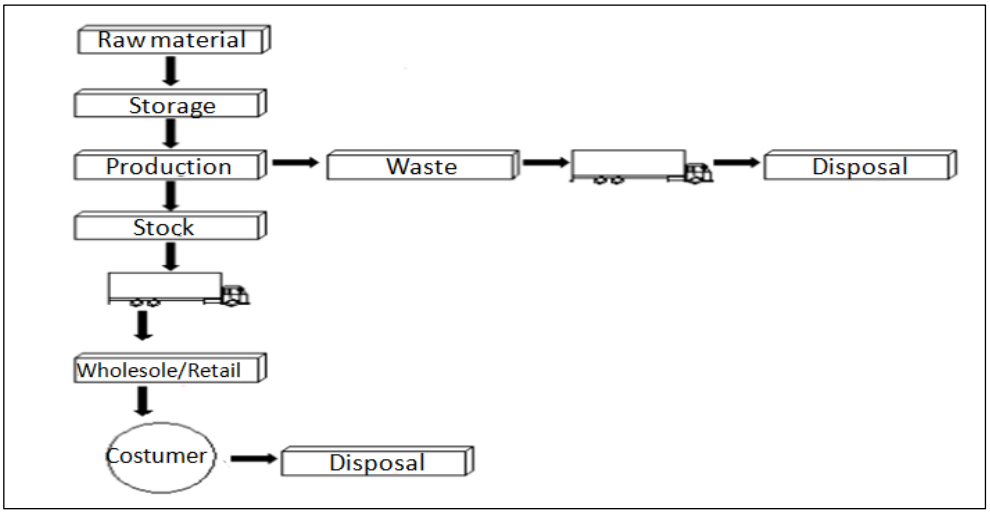

Figure 4: Product life cycle in the studied company.
Source: Authors, (2020).

During the production of all the company's products, waste is generated, such as wire, springs, pieces of paper, cardboard and plastic. These materials are sent to the sector responsible for dividing these waste categories, which makes it possible to sell these materials to a partner company that takes care of recycling them. However, this measure does not influence the materials in circulation after they leave for their customers, being uncontrollable the destinations given by consumers who often act inappropriately, letting it contaminate the environment. These products, in addition to having the potential to damage nature when disposed of inappropriately, contribute to the increase in paper production in order to meet the demand for this type of product.

IV.3 REVERSE FLOW IMPLEMENTATION PROPOSAL

Based on this situation, it is proposed to implement a reverse cycle of these products as a way of minimizing the circulation of these materials and their residues, contributing to the gain of prestige by the visibility of the company's name, with regard to involvement with projects. responsible production, gains from the loyalty of its customers and gains from the sale of products returned in this cycle, which may pass on part of this benefit to customers.

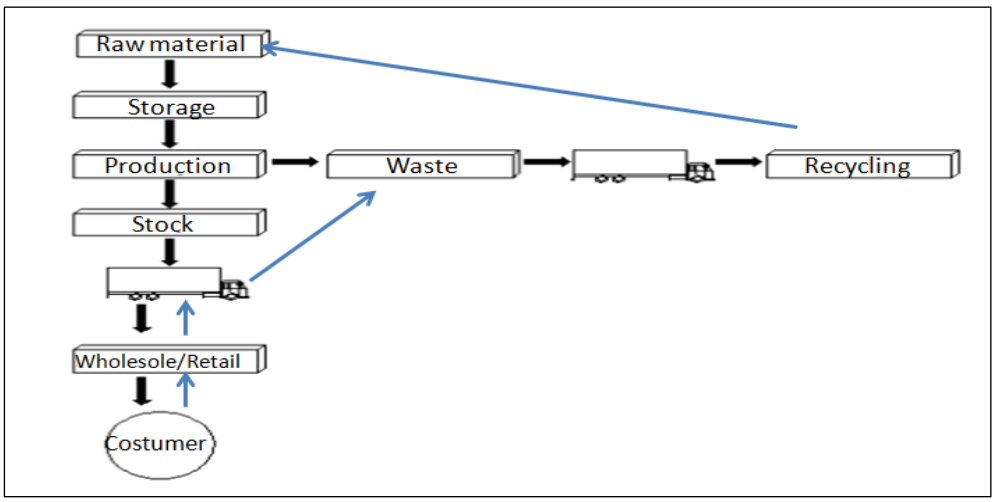

Figure 5: Reverse flow proposed to the studied company.
Source: Authors, (2020).

Figure 5 shows clearly how the implementation of this system would act in this type of process. The idea would be to implement a reverse system for these materials, where it was possible to reduce their waste, reduce the use of raw materials and enable a sustainable production cycle. Returning these products giving buyers the possibility of reducing environmental impacts

and at the same time benefiting them with an award in the form of a discount at the time of delivery of this material and purchase of a new product from the brand.

As for the logistics used in this return, one can perceive a potential in its costs, as it is a system that would take advantage of structures and transport already used in the current system of distribution of these products (Figure 4). The first stage focuses on the creation of collection points, strategically implemented with the four main buyers of materials produced by the company.

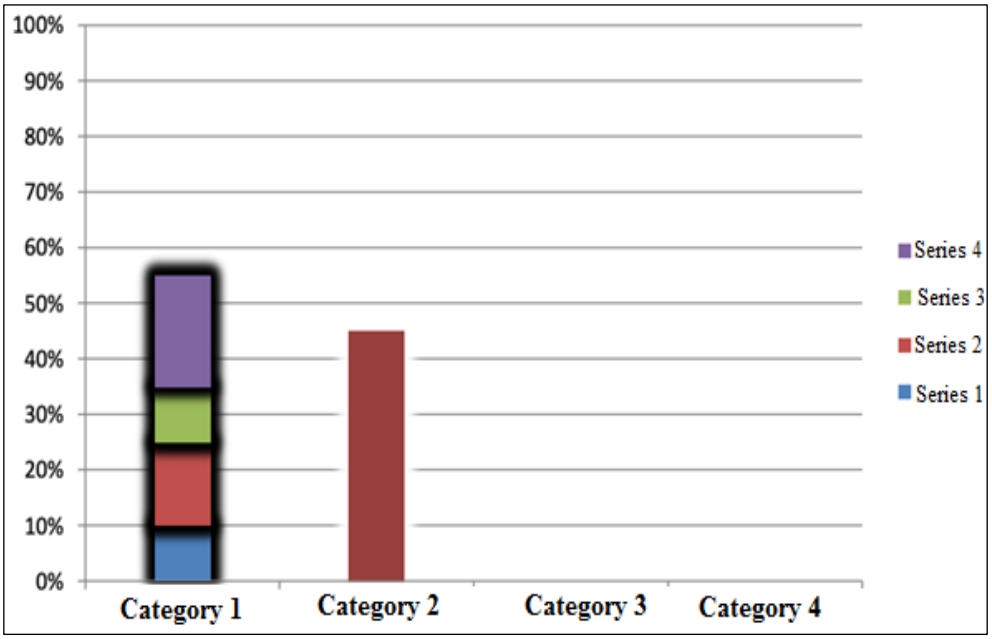

Figure 6: Potential Buyers Chart.
Source: Authors, (2020).

The chart of potential buyers represents the company's current sales, showing that 55% percent of sales are given to four large buyers, which brings the initial focus of installing collection points to these four customers, making it possible to attack a significant amount of products in a few points initially.

As a means of comparison, a Table 1 was made with the calculation of the values obtained from the sale of waste.

Table 1: Demonstration of values in the sale of waste.

Notebooks (10x1)	Material (Kg)	Price/Kg	Value Partial
paper	0,616	0,90	0,5544
cardboard	0,086	0,23	0,01978
spring	0,018	0,23	0,00414
Total			0,57832

Source: Authors, (2020).

Table 1 used as a calculation basis between the weight of each type of material contained in a ten-item notebook, multiplied by the resale value of these materials for the recycling industry. Therefore, the unit value obtained for each notebook that returns within the proposed reverse cycle is obtained.

Table 2: Values by notebook template.

Notebooks	Return Value (BRL)
1x1	0,29032
10x1	0,57832
15x1	0,85552
20x1	1,13272

Source: Authors, (2020).

Table 2 shows the values obtained for each type of notebook within this cycle, which allows us to analyze the balance of the return values of each type of notebook, which by calculations represent between 7.5% of the most expensive model sold by the company and 10% of the cheapest model, which gives us an average of 8.75% based on sales figures.

After all these crossings of information were made, a survey was made to calculate the profitable potential of this project. The values obtained with the return of these products if we think of an approximate number of 50% of return would allow an approximate figure of R$ 920 thousand, being passed on to the clients part of these values as benefits for the purchase of a new product of the brand.

However, for an efficient implementation of the reverse cycle, it is necessary to use the technology that has been evolving to develop various systems and architectures for control, supervision and data acquisition in different types of industries or processes such as, for example, a SCADA system, which provides reliability, flexibility, increased production and improvements in operating conditions. In addition, losses, accidents due to human errors decrease, product efficiency and quality increase with a decrease in production costs [22].

V. CONCLUSIONS

From this research, it was possible to analyze the entire product cycle, applying reverse logistics techniques to it, where it became clear the importance of this system as a way to minimize impacts to the environment.

After the field research and the proposal to implement a reverse cycle for these products within the company "PAPER S.A", the potential for the project regarding the system implementation measures became clear. Because no type of investment with facilities, machinery or vehicle availability would be necessary, since all of these are already part of the current production system.

As for profitable benefits, it was found through an analysis of the values obtained by the return of these materials that this

system is capable of generating a significant amount of benefits to all the links involved, such as customers, resellers, the recycling industry and the industry itself producer. Because the system is capable of producing resale values in the brand of up to 10% of the value of the product.

Through this system and after the analysis it was possible to notice that the recycling industry will benefit from the growth in the quantity of products destined for this activity, also strengthening this type of market.

The proposal to implement a reverse logistics system for after-sales and post-consumer goods applied to the school materials production industry proved to be efficient in all the points analyzed during this research, being a system beneficial not only to the market, but also to the environment and that benefits the whole society. However, future studies are recommended that compare the best information systems for the implementation of more efficient reverse cycles.

VI. ACKNOWLEDGMENTS

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RESEARCH ARTICLE OPEN ACCESS

INFILTRATION: THE DISEASE OF THE STRUCTURE

Deborah Ewely Batista Pinto[1], Bianka Caroline Cunha Firmino[2], Marcus Cruz dos Santos[3], Wanderson Batista da Rocha Caetano Carvalho[4], Luis Carlos Silva de Oliveira[5] and Robson Edgard Farias[6]

[1, 2, 3, 4, 5, 6] Blauro Cardoso de Mattos Higher Education Institute - FASERRA. Manaus–Amazonas, Brazil.

Email: eng.deborahbp@gmail.com, biankakarolinne@gmail.com, santos.m.0752@gmail.com, engenheirocivilwb@gmail.com, luizcivil001@gmail.com, robsonedfaria@yahoo.com.br

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ABSTRACT

In civil construction, moisture has been highlighted as the main cause of infiltration, with the solution of waterproofing systems that aim to protect the environment. About this issue, this article aims to analyze and elucidate the infiltration process and it is consequences. In order to respond to the research objectives, the methodological choice was an exploratory and descriptive bibliographic review on the forms of pathological manifestation the buildings can present when affected by humidity. The research results show that the poor execution of the project and the lack of waterproofing in the structure are the main causes of structural pathologies. Found that the problem, the repair must be immediate. In addition, the study discusses the techniques and elements that should be used to avoid corrective repairs, preventing financial disorders, structural problems, public health and worsening of respiratory allergies in humans.

I. INTRODUCTION

Moisture is the biggest cause of infiltration and waterproofing systems are the recommended solution to protect the environment from this pathology, as it creates an impediment to the infiltration of water or directs to another location that is not affected by the fluid. In Brazil, the first appearance of this procedure was in the construction of the *São Paulo* subway, as it is a large project, an effective strategy was needed to combat this pathology in the future; then, the Brazilian Institute of Impermeabilization (IBI) was born, adopting this procedure in which whale oil was mixed with settlement mortar and cover [1].

According to [2], humidity has always been a cause of concern since man lived in caves, as they realized that moisture penetrated the walls through the soil, which made housing conditions dangerous and could cause unhealthy conditions in those caves. It was noted that water has a high penetrating power in various materials [2].

By ignoring important factors in the construction stage, such as the appropriate material, a team qualified to carry out the application of the waterproof coating and the type of system ideal for the situation, can lead to future problems due to humidity. However, this activity goes far beyond the merits of the construction, it shows that planning is essential and indispensable in any work, professionals in the area must have high technical knowledge to act, thus avoiding future complications [3].

To [3] water is the biggest cause of pathologies in buildings. Water has the ability to cause degradation in structural construction, damage to paint along with health problems, as moisture penetrating the wall can cause respiratory diseases through fungi and bacteria, causing an unhealthy environment and harming health.

An evolution in civil construction was noted in terms of works management, but according to [1], waterproofing is missing in most works, as it is often considered expensive and therefore is soon discarded for not being noticed visually its existence or not [4].

According to [5], the right choice of products and the system applied for waterproofing is extremely important in the future there is no need for intervention for repairs or renovations. The cost of waterproofing during the work is from 0.45% to 1.95% and if there is a need for repairs due to lack of it, the cost goes up about 15%, because if there is no corrective or preventive intervention, the useful life of the work decreases according to the deterioration of the structure exposed to infiltration [6].

As a result, this bibliographic review article was developed through searches in scientific Institute of Technology and Education Galileo of the Amazon (ITEGAM), Google

Scholar, and others, using the keywords: "infiltration"; "infiltration into structures"; "Infiltration" + "waterproofing", "structural pathologies" and "civil construction" + "infiltration", having as factors the correct use of waterproofing and how the incorrect use of this process can cause damage to the structure, showing the origin and solution of the problem [7].

II. WATERPROOFING

With changes in the construction method, which went from corrective to preventive, waterproofing is still difficult to fit into the planning of some works.

In the research related to the damages that the lack of a correct waterproofing can cause to the structure, questions arise in which circumstances the problems caused by the pathology can be related not only by the misuse of the products, but also by the carelessness at the time of the execution of the project.

Waterproofing is the set of operations and construction techniques (services), composed of one or more layers, whose purpose is to protect buildings against the deleterious action of fluids, vapors or moisture [7].

According to [7], the waterproofing project is divided into two: the basic project and the executive project. The basic project contains the fundamental information for the waterproofing to be done correctly. Fulfilling the function of protecting the building from moisture. It must be carry out for works of multifamily, commercial, mixed, industrial buildings, as well as for tunnels, dams and works of art, by the same person responsible for the legal architecture project [7], according to [8]. The executive project is the union of information based on the basic waterproofing project, however it has detailed specifications of all waterproofing systems to be used in the construction. In addition, the project must be done taking into account the existence of the architectural, structural, hydraulic-sanitary, rainwater, gas and electrical projects so as not to cause problems with overloads, detailing, and even with the aesthetics of the building [8].

The appropriate type of waterproofing to be used in civil construction must be determined according to the request imposed by the fluid on the construction parts that require tightness. The request can occur in four different ways, as follows:

- imposed by percolating water;
- imposed by the condensation water;
- imposed by soil moisture;
- imposed by the fluid on unilateral or bilateral pressure [7].

III. MANIFESTATION OF INFILTRATION

Pathological manifestations of infiltrations can occur in several ways, with which they can be detected visually through specific tests, analyzes or calculations.

Often, only visual observation can cause uncertainties about the pathology, due to the fact that several of these symptoms are not specific to a given type of infiltration [9].

It can be said that the humidity in a building manifests itself in several different ways, among which stand out:

- humidity by capillarity;
- building humidity;
- precipitation humidity;
- humidity due to other causes.

III.1 DEFINITION OF THE MAIN RESEARCH CENCEITES AND PARAMETERS

Capillarity consists of the phenomenon of rising water from the soil on the walls of a building through surface tension. The intensity of the surface tension is directly related to the viscosity of the liquid.

The water rises on the walls through the capillaries, which come from the discontinuity of the materials used in civil construction, forming a network of spaces filled with air, which are being saturated by the water as it moves within the material [10].

Not only water from the soil, but also the salts on the ground and in the building materials themselves are dissolved by the water and transported through the walls to higher levels. Upon evaporation, this water will cause the crystallization of these salts that will close the existing pores, reducing their permeability and increasing the level of humidity [11].

The action of water by capillarity is visually perceived, as it causes the appearance of spots in the regions usually close to the ground, accompanied by mold spots, cryptoflowering, efflorescence or parasitic vegetation, especially in places with poor ventilation.

In the Figure 1, shows a pathology found in a building in the city of Manaus, AM. It was identified that the wall is in parallel with the ground. This causes water to percolate from the soil to the inner side of the wall and can manifest diseases caused by the accumulation of fungi.

Figure 1: Wall with pathology caused by capillarity.
Source: Authors, (2020).

III.2 DEFINITION OF THE RESEARCH STRATEGY

Most materials require water for mixing, some of that water evaporates more easily, the other part takes longer. In this process, the most porous materials use three distinct phases. The first phase, the evaporation of surface water. The second phase, the water that is retained in the pores with the largest diameter where it takes a longer time to evaporate. In the third phase, the water that is trapped in the smaller diameter pores begins to be released in a slower process, which can happen for years. In general, the pathologies found due to this type of humidity tend to cease for a more or less short period, depending on the characteristics of the type of use of the enterprise and the climatic region that is found [12].

III.3 PRECIPITATION HUMIDITY

In this type of humidity, we will have the appearance of stains on the external walls or slabs in different dimensions. During periods of precipitation, they tend to appear and during prolonged periods of rain, mold, efflorescences and cryptoflorescences may appear [12].

III.4 HUMIDITY DUE TO OTHER CAUSES

This humidity has many types of occurrences, it becomes very difficult to summarize all its causes in a specific way. Its causes are usually the result of installation failures, defects in construction, accidents or even lack of maintenance [12].

IV. MANIFESTATION OF INFILTRATION IN WET AREA

In civil construction, water permeates the empty spaces of some solid body, which are divided into two distinct groups.

One says about the infiltration that occurs from the outside in, caused by precipitation, humidity, soil type or groundwater action. The other group, on the other hand, concerns infiltrations from the inside out, which appear through leaks in the hydraulic network due to poor installation, inadequate material, or the absence of adequate coatings to act in wet areas [13].

In infiltrations from the wet area, where there is a process to know where, and how the pathology arose, usually caused by failure or absence of waterproofing.

The humidity as it increases, causes an expansion of the material, and when it decreases the contraction is proven. Hygroscopic changes influence the deformability characteristics of masonry, as they cause the dimensional changes they perform (Figure 2). Volumetric variation can cause cracks, and is similar to those caused by shrinkage [14].

Figure 2: Infiltration in reinforced concrete slab.
Source: Authors, (2020).

According to [6], the executive waterproofing project must meet some constructive details such as the diameter of the hydraulic collectors, on the expansion joints, external pipes, vertical waterproofing plans [5].

According to [14], the cost of implementing a waterproofing project in the work varies from 1% to 3% of the total value, involving design, execution, consultancy, inspection and materials. And when the implementation is not carried out, these costs reach up to 15% of the total value of the work [15].

V. WATERPROOFING PROCESS

Choosing an appropriate material for the waterproofing process must undergo a careful analysis in view of the circumstance of the place where the material will be used, because for the purpose of waterproofing there will be a specific material. Some materials that stand out are: asphalt, cement mortar and polymeric resins [16].

According to [15] the existing waterproofing systems are:

- Flexible membranes molded in loco;
- Pre-molded flexible blankets;
- Molded rigid membranes [17].

The type of waterproofing chosen depends on characteristics and working conditions, such as:

Condensed water: able to withstand the action of water on the structure by the condensation process.

Percolation water: resists percolation water without confinement in slabs for example.

Water by soil moisture: supports the action of water on floors in contact with soil or mold on walls [18].

Some waterproofing systems are chosen according to the characteristics of the work, mechanical resistance, cost, environment etc. Waterproofing systems are:

Water repellents: They chase away water, being able to apply it directly on the surface and it is indicated for exposed concrete, stone facades, ceramic tile and porous ceramic.

Crystallizers: Mixing an adhesive component with a cementitious component, creates a consistency and applying it on a wet surface, crystals are formed that when they dry, create a protective barrier.

Polymeric Mortar: Composed of additives, cement, polymers and aggregates. Must be used in cold areas as it is a waterproof coating.

Acrylic emulsion: Must be used on exposed surfaces. It is a liquid membrane, applying it cold and molding it in the applied area.

Asphalt emulsion: Must be used in slabs and cold areas. It is a single component inserted in the place like paint.

Asphalt emulsion: Must be used in slabs and cold areas. It is a single component inserted in the place like painting.

Caulker: Must be used for general waterproofing use.

Water repellent: Expels excess water. Suitable for use on bricks, stone facades, ceramic tile and porous ceramic [19].

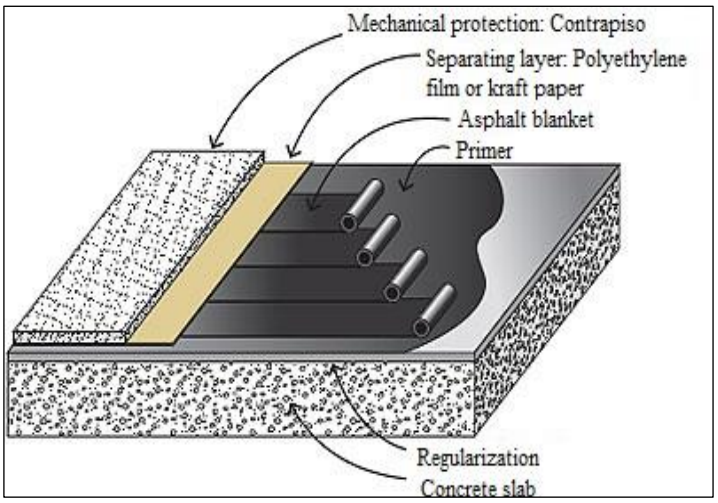

Figure 3: Waterproofing of asphalt blanket on a slab.
Source: Adapted of [20].

Table 1: Summary of waterproofing solutions.

Localization	Solution	Materials
Foundations	Solid brick masonry	Crystallizers
Buried structures	Outside	Asphalt blanket + Drain
Buried structures	Inside	Polymer mortar
Slabs	Waterproofing	Asphalt blanket and acrylic membranes
Reservoirs	Lifts	Asphalt blanket and PVC blanket
Reservoirs	Buried	Polymeric mortar and acrylic membranes

Source: Authors, (2020).

VI. THE IMPORTANCE OF WATERPROOFING IN BUILDING

The waterproofing prevents water from coming into contact with the materials, preventing infiltration, stains, mold, peeling, efflorescence, corrosion of the armature, among other pathologies. Without proper waterproofing, these claims can occur in wet areas such as slabs, pools, walls that receive water from precipitation, reservoirs and others.

The sealing and sealing of the pores depends on the correct waterproofing, since without its correct application, the construction will fail. With the waterproofing carried out properly, the environment will be safe from recurring pathologies the action of water is comfortable for the regulars and residents of the building.

This process is one of the most important stages in civil construction, and sometimes it is not applied due to lack of resources or cut in the budgetary expenses of the work, thus causing future problems in the building.

Many construction companies choose to install the waterproofing only at the end of the work, but the sooner it is applied, the more effective it will be, avoiding problems during the construction, as they result in an unpleasant humidity.

VII. MOFO AND BOLOR: DAMAGE TO HEALTH

In addition to the infiltration damaging the structure with mold and mildew, it can cause residents respiratory diseases. Mold and mildew are caused by fungi that proliferate in humid environments, caused by poor ventilation, infiltration and by closed environments.

Children, the elderly, allergic and pregnant people are at risk for acquiring respiratory diseases due to mold and mildew, such as sinusitis and even asthma. In addition to diseases they cause unpleasant spots on the structure and a bad smell.

The solution to this pathology caused by infiltration is waterproofing. Other ways to also get rid of mold and mildew is by opening ventilation at the site.

Mold and mildew have differences. Mold erodes the affected material and mold infects the object. They are housed in closets, clothes, walls and furniture.

Figure 4: Wall mold caused by moisture.
Source: Authors, (2020).

Figure 5: Mold infecting the object.
Source: Authors, (2020).

VIII. CONCLUSION

In this article, some pathologies of civil construction were addressed, with the objective of showing the importance of the lack of waterproofing caused in homes and how much this is harmful to the enterprise and even the health of the residents. The failures related to waterproofing are usually caused by the lack of specialization of professionals who do not use the minimum standards for the preparation of the project, technical standards are available to the construction professional so that infiltration does not occur at any time. It was noted that in most cases it is due to the fact that there are no mandatory rules for a waterproofing project in single-family homes, in which those responsible for the work choose the cost, thus making waterproofing an option, leaving aside its great role in the project, if it was mandatory in the initial phase of the work, maintenance costs can reach 15% of the total value of the work, whereas this cost can reach up to 50% of the repair value at the affected site, if it is not carried out at the time of the activity.

All the pathologies presented show that the failures, in general, can be concluded as negligence arising from the lack of training of the professionals involved, since most of the single-family homes where the infiltrations occurred were recently carried out and emergency maintenance was not yet necessary. The current norms present, in addition to concepts, minimum requirements for the correct functioning of the structure to be built, thus the professionals registered in the CREA system can guarantee the project's efficiency, thus following all the requirements, since the normal are studied in detail by the commissions studies, thus making possible the standardization of the content presented. Having new solutions to consolidate the problem has to be constant, so being aware of new research technologies, bring advantages increasingly demanded by the job market, thereby prioritizing human life.

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RESEARCH ARTICLE OPEN ACCESS

DESIGN PERFORMANCE OF LEAD AND LAG COMPENSATOR USING OPAMP AND ROOT LOCUS APPROACH THROUGH SIMULATION TOOL

Badri Narayan Mohapatra[1] and Jijnyasa Joshi[2]

[1, 2] Department of Instrumentation & Control of AISSMS IOIT, University of Savitribai Phule Pune University – SPPU. Pune, 411001, India.

[1]http://orcid.org/0000-0003-1906-9932

Email: badri1.mohapatra@gmail.com, aissmsiit@gmail.com

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ABSTRACT

The design objective behind lead and lag compensator is to meet the relative stability as well as to meet desired performance. Both in time domain or frequency domain, the compensator design can be carried out. Absolute stability of a system can be predicted from root locus approach. Simulation tool like tinkercad and wolfram alpha can provide easy access of different control engineering design performance, so that it helps all under graduate, post graduate and researchers can able to apply their knowledge to engineering application from any computing environment. And they can perform it at any time. By this passive learning is also possible with active engagement in the learning related to practical and theory. To judgment and easily understand on simulation, student can modify their design specification and get deeper knowledge on control system design engineering. one can also use opamp circuit to understand the compensator design performance.

I. INTRODUCTION

Now a day's learning and designs can be enhanced through interactive tool. Due to personal computer and especially smart mobile phone can make it possible to solve sophisticated control system problems with easy, simple and concise manner. Level of competences increase only when students will go for practice. Design and tuning by adding different pole and zero parameter to the system, stability can be increases as per required performance. The basic principle should necessary to remember for all engineering students. Different computing tool can help students and instructor to teach and learn process due to covid19 pandemic situation. Basic opamp circuit is used for lead and lag compensator [1]. The main aim of the research behind is that the importance of pole position and its effect is important, as one of the researcher have already find the control of helicopter model [2]. Different virtual laboratory are there for easily the experiment can be carried out for system designing, implementing and controlling [3]. Laboratory experiments play a vital role in control system design, theory to apply in design concept which is more important [4]. The fundamental concept can be understand by basic text book of control system design [5], automatic control system [6] and control system engineering [7].

II. LEAD AND LAG OPAMP CIRCUIT

Many parameters involved in the real world and different parameter involve with physical quantity and all things can be represented in mathematical model. From many decades opamp have been used for many applications. Many popular text book treat different work concept with variety of application. There are lot of analog ckt tools available where one can easily implement the concept of opamp. Figure 1 and 3 are the respective lead and lag opamp circuit.

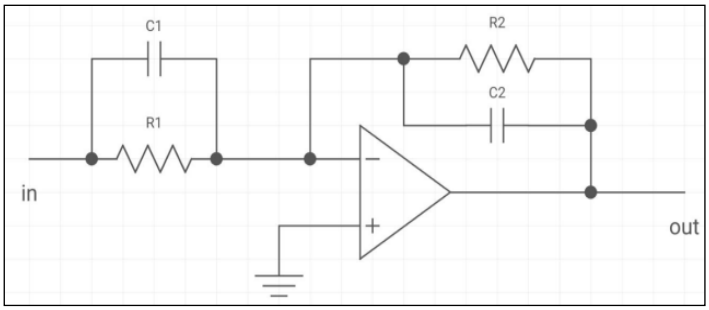

Figure 1: Lead Compensator (R1C1> R2C2).
Source: Authors, (2020).

For the concept of lead and lag here we are analyzing through tinkercad and wolfram tool. Connect opamp Ics (741) on the breadboard then take resistors (R1=358 Kilo ohms, R2=179 kilo ohms,) and 4 capacitors(C1=5.6 micro farad,C2=0.1 micro farad for lead compensator design as R1C1 should be greater than R2C2. similarly, R3=179 kilo ohms, R4=358 kilo ohms C3=0.1 micro farad, C4=5.6 micro farad for lag compensator. And connect them in parallel combination with each other (R1C1, R2C2 for lead design and for lag compensator design take R3C3, R4C4).

Connect R1C1 and R3C3 combinations to the pin number 2 of the opamp ICs respectively such that one terminal of the parallel combination (of the resistor and capacitor) should be connected to the power supply and the R2C2 and R4C4 combination to the pin number 6 of the opamp ICs respectively so that they are grounded.

After that make ground the pin number 3 of both the opamp ICs and connect the pin number 4 of both opamp ICs to the power supply (-ve). Connect pin number 7 of both the opamp ICs to the power supply (+ve). Now connect pin number 2 with pin number 6 of both the opamp ICs. Now using a function generator provide power supply through the breadboard.

Connect power supply (+ve) to the breadboard (i.e. by connecting the positive terminal to positive end of the breadboard and negative terminal to the negative terminal of the breadboard).

8) Now connect other power supply (-ve) to the breadboard (i.e. by connecting the positive terminal to negative end of the breadboard and negative terminal to the positive terminal of the breadboard). Now connect oscilloscopes to two to the input and two for the output. For input, connect the positive terminal of the oscilloscope to the power supply on the breadboard and the negative terminal is to be grounded.

10) Now connect the remaining two oscilloscopes by connecting the positive terminal of the oscilloscope to the power supply on the breadboard and negative terminal is to be connected to the parallel combination of the resistor and capacitor (R2C2 and R4C4). Also interconnect the positive terminals of the breadboard and the negative terminals with each other (+ve to +ve and -ve to -ve). The simulation results for lead and lag circuit is carried out through tinkercad circuit tool [8].

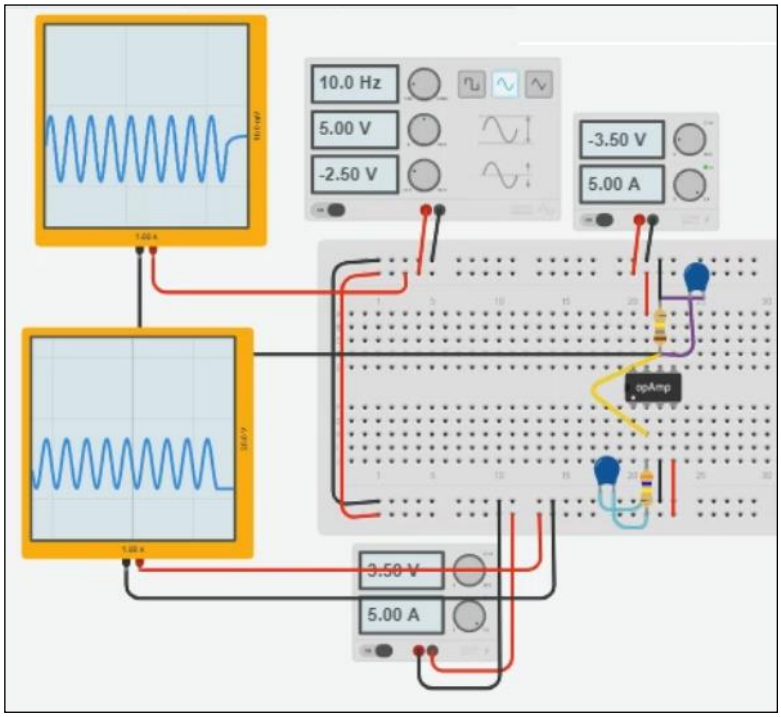

Figure 2: Lead Compensator using opamp circuit.
Source: Authors, (2020).

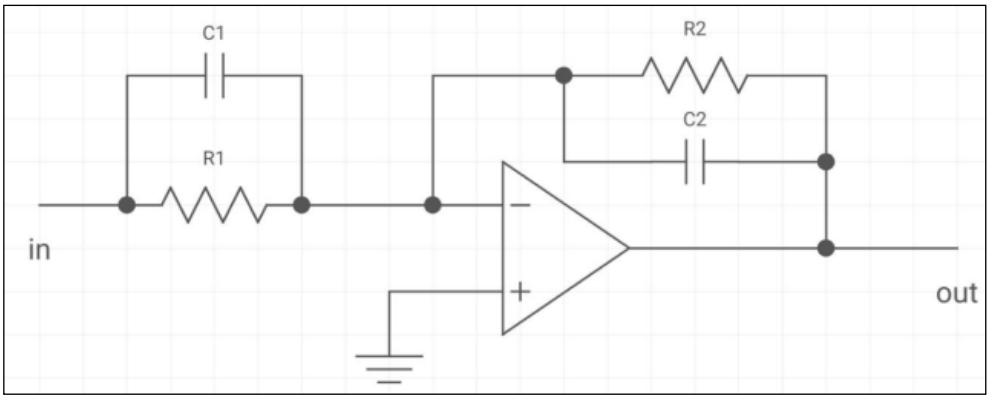

Figure 3: Lag Compensator (R1C1< R2C2).
Source: Authors, (2020).

The effects of lead and lag compensator shows in oscilloscope Figure 2 and 4. Normally damping which will be more in case of led compensator. Due to this less rise time and less overshoot.

With the observation from oscilloscope one can easily find the lead and lag phase difference. Depending on the values of register and capacitor, the circuit behaves as lead and as well as lag. Any type of correction if a system will require then compensator circuit is very useful. Some cases lead lag compensator that is combination circuit is also useful. Satellite launching, automobile, robotic control its use is more.

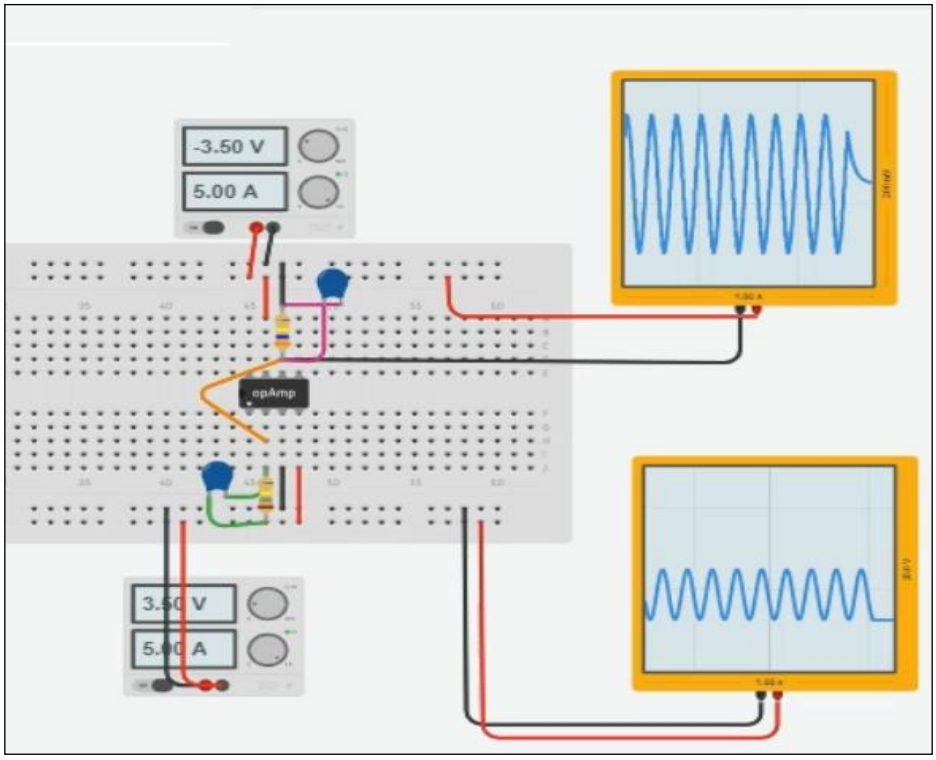

Figure 4: Lag Compensator using opamp circuit.
Source: Authors, (2020).

III. ROOT LOCUS APPROACH

A pair of pole-zero has to be form for realization of compensated network. If a network having pole nearer to imaginary axis then it introduces a lag network. In general compensating represented as:

Compensator network:

$$G(s) = \frac{(s + a)}{(s + b)} \quad (1)$$

If a>b it's lag, if a<b its lead

Consider a system:

$$G(s) = \frac{100}{s(s + 9)} \quad (2)$$

Depend upon the value of value of zero and pole the compensator may lead type (a<b) or lag type (a>b).

Lead Compensator network:

$$G(s)G_c = \frac{100}{s(s + 9)} \frac{(s + 10)}{(s + 16)} \quad (3)$$

Lag Compensator network:

$$G(s).G_c = \frac{100}{s(s + 9)} \frac{(s + 10)}{(s + 0.0016)} \quad (4)$$

Here we are considering as an example of a system gain as per Equation 2 but for that system if someone will add a compensator network, then the output response in the root locus plot which will vary like close and away from the origin. The root locus of the main considered system is shown in Figure 5 but if lead network or lag compensator network will be introduced then the output is shown in Figure 6 and Figure7. The simulation result which was carried by the wolfram alpha tool [9].

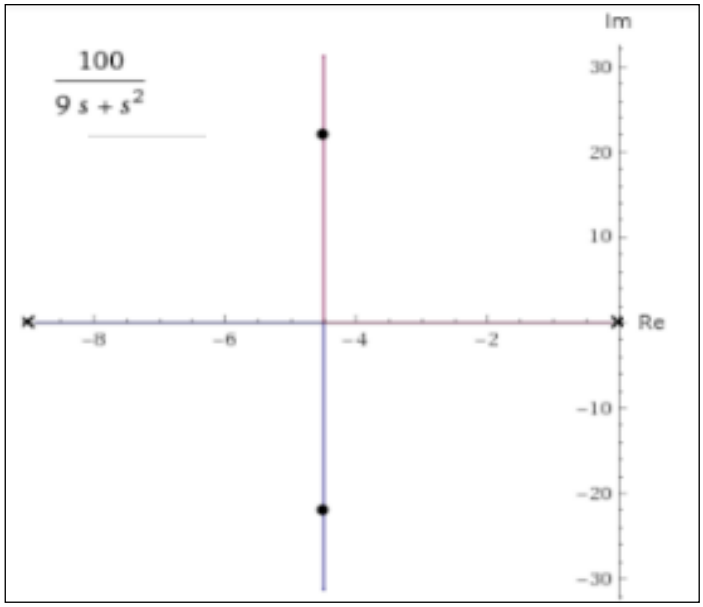

Figure 5: Root locus for uncompensated system.
Source: Authors, (2020).

As per the equation written in 1, based on that one can say what type of compensator should be require for a system output performance. As from Figure 5 as it is in stable condition even after if someone will go for lag or lead then how the response change that can easily observable through root locus simulation.

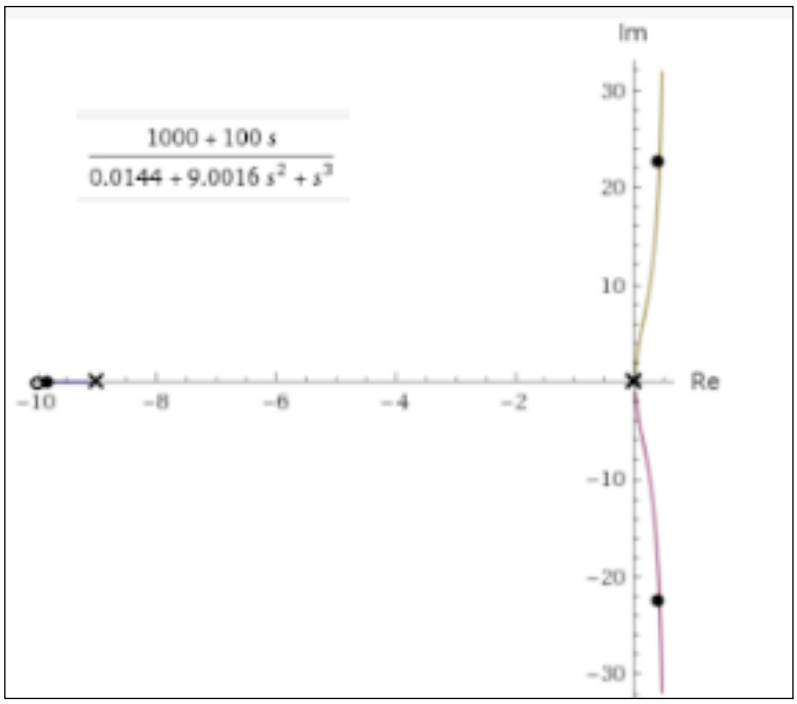

Figure 6: Root locus for lag network.
Source: Authors, (2020).

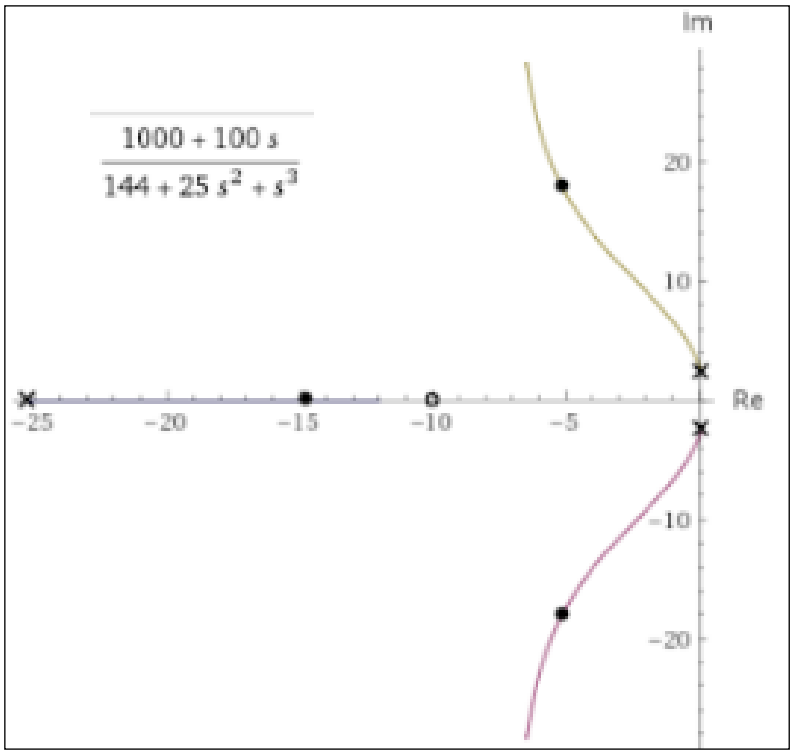

Figure 7: Root locus for lead network.
Source: Authors, (2020).

IV. CONCLUSIONS

In this research result we can easily visualize the phase difference in oscilloscope by drag and drop of all require components to the breadboard and simple connection as per circuit connection by using tinkercad. Secondly, we can compare lead and lag by proper value choosing for compensator so that the root locus line, which will indicate the system stability using mathematical tool. This type of simple research may help students on lead and lag concept with analysis of mathematical model. Root locus and lead and lag compensator may help undergraduate students about the stability of the system. such type of

computational tool can help students for their choice of different control by choosing by their own choice value and this way they can understand the problem and concept behind control theory.

To make students learn easily, effort has been expanded through web base tool. Many concepts can be analysis with fast and deep easily through interactive tool.

V. ACKNOWLEDGMENTS

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