Journal of Engineering and Technology for Industrial Applications

ISSN 2447-0228

December 2023 Volume 09 / No 44

Editor-in-Chief: J. C. Leite

www.itegam-jetia.org

ITEGAM - JETIA ISSN 2447-0228 Online
Journal of Engineering and Technology for Industrial Applications (JETIA)

O **ITEGAM-JETIA: Journal of Engineering and Technology for Industrial Applications** is a publication of the Galileo Institute of Technology and Education of the Amazon (ITEGAM), located in the city of Manaus since 2008. JETIA publishes original scientific articles covering all aspects of engineering. Our goal is the dissemination of research original, useful and relevant presenting new knowledge on theoretical or practical aspects of methodologies and methods used in engineering or leading to improvements in professional practice. All the conclusions presented in the articles It should be state-of-the-art and supported by current rigorous analysis and balanced assessment. Public magazine scientific and technological research articles, review articles and case studies.
JETIA will address topics from the following areas of knowledge: Mechanical Engineering, Civil Engineering, Materials and Mineralogy, Geosciences, Environment, Information and Decision Systems, Processes and Energy, Electrical and Automation, Mechatronics, Biotechnology and other Engineering related areas.

Publication Information:
ITEGAM-JETIA (ISSN 2447-0228), (online) is published by Galileo Institute of Technology and Education of the Amazon on a every two months (February, April, June, August, October and December).

Contact information:

Web page: www.itegam-jetia.org
Email: editor@itegam-jetia.org
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.

Previous Notice
All statements, methods, instructions and ideas are the sole responsibility of the authors and do not necessarily represent the view of ITEGAM -JETIA. The publisher is not responsible for any damage and / or damage to the use of the contents of this journal. The concepts and opinions expressed in the articles are the sole responsibility of the authors.

Directory

ITEGAM - JETIA ISSN 2447-0228 Online
Journal of Engineering and Technology for Industrial Applications (JETIA)

ITEGAM-JETIA. v.9, n.44. December of 2023. Manaus - Amazonas, Brazil. ISSN 2447-0228 (ONLINE)
https://www.itegam-jetia.org

SUMMARY

MONITORING OF ANNUAL EFFECTIVE DOSE (AED) IN SURFACE SOILS OF AHERO RICE FIELDS, KENYA **4**
Mukanda Kere Wanyama, Michael Nakitare Waswa and Linda Ouma

SCALE-UP BY MATHEMATICAL MODELING OF ANAEROBIC REACTORS FOR YEAST WASTEWATER TREATMENT **9**
Gabriel Alejandro Iglesias Barreto and Iván Leandro Rodríguez Rico

THE USE OF PERMEABLE ASPHALT FOR THE BENEFIT OF DRAINAGE SYSTEMS IN URBAN AREAS - A LITERATURE REVIEW **18**
Knopy Lima Lustosa, Francisco Luís da Silva dos Santos Júnior and Heyder de Souza Castro Oliveira

SINGLE SERVER-SIDE AND MULTIPLE VIRTUAL SERVER-SIDE ARCHITECTURES: PERFORMANCE ANALYSIS ON PROXMOX VE FOR E-LEARNING SYSTEMS **25**
Yuri Ariyanto

LOGISTICS MANAGEMENT: A FUTURE PERSPECTIVE ON LOGISTICS PROCESSES WITH THE APPLICATION OF THE 5S METHOD AT BRAMAM COMPANY IN PARINTINS, AMAZONAS **35**
Roberta Pontes da Costa, Thiago Mendonça de Souza, Bruna Lorrayne Vasconcelos Barros, Vanessa Coelho da Silva, Emanuel Kedson da Silva Freitas and Aderli Vasconcelos Simões

DEVELOPMENT OF AN EXTERNAL PUMP FOR OIL TRANSFER FOR MAINTENANCE OF TRUCK LIFTING PLATFORMS **49**
Anderson Bittencourt Gimack, Antônio Clisma Dantas de Oliveira, Douglas Pereira de Souza and Marcus Renato Pinheiro Mattos

PROCESS MAPPING: A CASE STUDY IN THE CONTRACT SECTOR OF THE PUBLIC DEFENDER'S OFFICE IN THE STATE OF AMAZONAS **54**
Rafaela Barbosa Nascimento, Elton Pereira Teixeira, Orlem Pinheiro de Lima, Márcia Ribeiro Maduro, Vanessa Coelho da Silva and Wlademir Leite Correia Filho

Journal of Engineering and Technology for Industrial Applications

ITEGAM-JETIA

Manaus, v.9 n.44, p. 4-8. Nov/Dec, 2023

DOI: https://doi.org/10.5935/jetia.v9i44.883

ISSN ONLINE: 2447-0228

RESEARCH ARTICLE OPEN ACCESS

MONITORING OF ANNUAL EFFECTIVE DOSE (AED) IN SURFACE SOILS OF AHERO RICE FIELDS, KENYA

Mukanda Kere Wanyama*[1], Michael Nakitare Waswa[2] and Linda Ouma[3]

[1, 2, 3] Department of Science, Technology and Engineering, Kibabii University, P.O BOX 1699 - 50200, Bungoma, Kenya.

[1] http://orcid.org/0000-0003-2667-8525, [2] http://orcid.org/0000-0003-2479-862X, [3] http://orcid.org/0000-0002-4975-2495

Email: *kerewanyama2018@gmail.com, mwaswa@kibu.ac.ke, louma@kibu.ac.ke

ARTICLE INFO

Article History
Received: August 07th, 2023
Revised: November 09th, 2023
Accepted: December 12th, 2023
Published: December 30th, 2023

Keywords:
Ahero Rice Fields,
Gamma Ray Spectrometry,
Sodium Iodide Thallium Doped Detector,
AED (IN),
AED (OUT).

ABSTRACT

The annual effective doses (AED) both AED (in) and AED (out) in the surface soils of Ahero rice fields, Kenya were investigated. The associated health risk of the soils from the four fields Field 1, Field 2, Field 3 and Field 4 was measured using gamma ray spectrometric technique employing Sodium Iodide Thallium doped detector. Five surface soil samples were collected at a depth of 15 – 20 cm from the Field 1, Field 2, Field 3 and two samples from Field 4. The average AED (in) of 0.30 ± 0.01 mSv/y and an average AED (out) of 0.20 ± 0.01 mSv/y for field 1, an average AED (in) of 0.19 ± 0.01 mSv/y, an average AED (out) of 0.20 ± 0.01 mSv/y for field 2, an average AED (in) of 0.28 ± 0.01 mSv/y and an average AED (out) of 0.18 ± 0.01 mSv/y for field 3 and an average AED (in) of 0.34 ± 0.01 mSv/y and an average AED (out) of 0.23 ± 0.01 mSv/y for field 4. All the AED values both in and out from the four fields were below the recommended level of 1mSv/y. The values indicate that there is no health hazard associated with the surface soils of the study area to the farmers and the general population.

I. INTRODUCTION

The concentration of natural radionuclides of ^{238}U, ^{232}Th and singly occurring ^{40}K in the soils have a direct bearing on the terrestrial radiatiation [1]. The three radionuclides are found in significant concentrations in the soils [2]. It is worth noting that natural radioactivity depends on the geological formations of the place [3]. Anthropogenic activities especially Agricultural based ones in an attempt to replenish the soils with nutrients using inorganic fertilizers adds to the radioactivity levels to the soils [4]. The hazards of exposure due to the radionuclides has formed a basis of major concern in the recent times [5]. The associated effects of exposure to the varying levels of radiations from ^{238}U, ^{232}Th and ^{40}K have been broadly discussed in various literature [6]. The Ahero rice fields are part of the larger Nyando wetlands region. This region is characterized by a Precambrian system of granodiorites that are granitic in nature [7]. The granitic rocks have higher concentrations of ^{238}U [8]. It is estimated that every year there are 40000 new cancer cases and over 27000 deaths in Kenya [9]. ^{238}U and ^{232}Th are highly radiotoxic. Individuals exposed to high amounts of ^{232}Th have an increased risk of bone cancer while ingestion of large concentrations of ^{238}U can cause lung cancer and kidney damage [10]. ^{40}K on the other hand is a mineral required by the human body muscles to work efficiently. It helps in the functioning of the nerves and muscle contraction. However, too much of ^{40}K in the body can affect the working of the muscles of the heart; an irregular heart beat which may result in to heart attack and in worst cases death.

The farmers and the general public are in direct contact with the soil, fertilizers and untreated water from river Nyando [11]. They inhale the dust particles of the soils which find their way in to the body through the respiratory system [12]. The radionuclides of ^{238}U, ^{232}Th and ^{40}K have very long half-lives (1). Farming in Ahero fields is not void of use of inorganic fertilizers especially phosphatic ones. These phosphatic fertilizers originate from rocks that are highly rich in ^{238}U [13]. The addition and

hence accumulation of natural radionuclides in the top soils is potentially hazardous to the human health and environment [12]. According to a study by [14], there were cases of reported skin burns when the study was conducted at four health care providers. The skin burns can be attributed to the direct irradiation from the radionuclides. This study of monitoring annual effective doses (AED) both AED (in) and AED (out) in the surface soils of Ahero rice fields was therefore undertaken to assess the radiological risk associated with the interaction of the soils by the farmers and the general public since no similar study had been done at the study area.

II. MATERIALS AND METHODS

II.1 STUDY AREA

The present study was conducted at the Ahero rice fields (Ahero Irrigation Scheme - AIS). The study area is located on latitude on latitude 00˚9´´S and longitude 34˚56´´E and at an altitude of 1160m above sea level [7]. Ahero fields is found in Muhoroni Sub County that has a population of 151799 [15]. These fields are characterized by vertisols just like other National Irrigation Schemes [16]. The soils are suitable for irrigation of rice due to their low percolation rates. The source of water for irrigation in the Ahero fields is river Nyando whose river bed is also characterized by rocks of granitic nature [7]. Map showing Ahero Irrigation Scheme where the study was done is as shown in Figure 1 below.

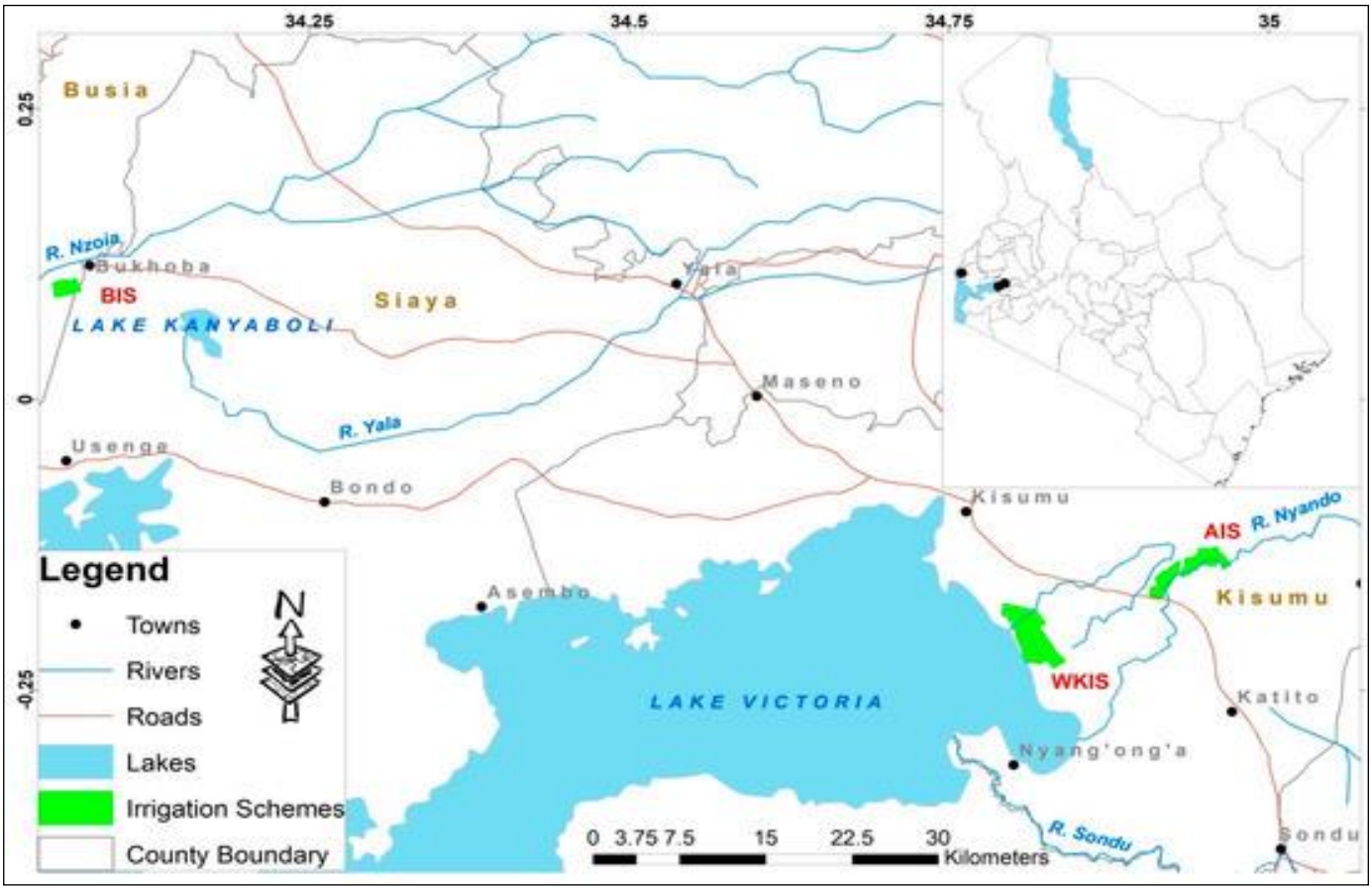


Figure 1: Map of Ahero irrigation scheme (Google maps).
Source: Authors, (2023).

II.2 SAMPLE COLLECTION AND PREPARATION

A total of 17 surface samples at the depths of 15 – 20 cm were collected. Samples S_1 to S_5 were from a field where rice was already transplanted (field 1), S_6 to S_{10} samples were collected from a field where transplanting was being done (field 2), S_{11} to S_{15} samples were collected from a field where rice had already been harvested and cultivation done (field 3), S_{16} and S_{17} samples were collected from a field that had not been cultivated for 2 years. The samples were properly labelled and spread on mats in the laboratory to dry for two weeks (14 days) to dry. They were then crushed using mortar and pestle then sieved through a 2.00 mm sieve (< 2.00 mm particles were used).

170 g of each sample from the fields was weighed in to cylindrical plastic containers of uniform geometry. The containers were properly labeled and hermetically sealed. The samples were then kept for 30 days to allow for 232Th and 238U and their short lived progenies to reach secular equilibrium before counting [17, 22].

II.3 GAMMA RAY SPECTROSCOPIC ANALYSIS

NaI (Ti) gamma ray spectrometer was used in the spectral acquisition and analysis [11]. The spectrometry system consisted of 76 mm by 76 mm single crystal of Thallium activated Sodium Iodide. Spectrum acquisition and processing was made possible

by coupling the detector output to a multichannel Analyzer (MCA). The energy calibration of the detector was done using the energy peaks of The energy calibration of the gamma ray spectrometer was done using the energy peaks of 662 KeV of ^{137}Cs**,** 1170 KeV and 1330 KeV of ^{60}Co (22). The masses used were 1.2g for ^{137}Cs and 6.7g for ^{60}Co.

Gamma rays from the soil sample strikes the NaI (Ti) crystal emitting photons that dislodge electrons from the photocathode. The photoelectrons produced are collected by the pre – amplifier and shaped into voltage pulses. The pulses are multiplied in the photomultiplier by a series of dynodes. Finally, the MCA digitizes the pulses and the output is displayed through personal computer.

III. RADIATION LEVEL MEASUREMENTS

III.1 ABSORBED DOSE RATE (ADR)

The ADR values shown in table 1 below used in the determination of AED were got from the study by [11] at the same study area.

Table 1: Absorbed Dose Rate of samples collected.

	Sample	Absorbed Dose Rate (nGy/h)
Field 1	S_1	98.35 ± 4.91
	S_2	67.73 ± 3.38
	S_3	130.84 ± 6.54
	S_4	53.40 ± 2.67
	S_5	57.18 ± 2.85
	Average ADR	$\mathbf{81.50 \pm 4.07}$
Field 2	S_6	62.68 ± 3.12
	S_7	44.55 ± 2.22
	S_8	47.81 ± 2.39
	S_9	61.12 ± 3.05
	S_{10}	$46.97.18 \pm 2.34$
	Average ADR	$\mathbf{52.59 \pm 2.62}$
Field 3	S_{11}	80.78 ± 4.03
	S_{12}	53.97 ± 2.69
	S_{13}	47.14 ± 2.35
	S_{14}	56.23 ± 2.81
	S_{15}	135.28 ± 6.76
	Average ADR	$\mathbf{74.68 \pm 3.73}$
Field 4	S_{16}	109.47 ± 5.47
	S_{17}	74.10 ± 3.70
	Average ADR	$\mathbf{91.79 \pm 4.59}$

Source: [11].

III.2 ANNUAL EFFECTIVE DOSE (AED)

In determining the outdoor AED to the population, the occupancy factor was put into consideration [18]. The annual effective dose AED (in) and AED (out) were determined using equations 1 and 2 respectively [19].

$$AED\,(\text{in}) = ADR \times 8760 \times 0.8 \times 0.7 \times 10^{-6} \quad (1)$$

$$AED\,(\text{out}) = ADR \times 8760 \times 0.4 \times 0.7 \times 10^{-6} \quad (2)$$

Where $AED\,(\text{in})$ and $AED\,(\text{out})$ are Annual Effective Doses for indoor and outdoor environments respectively, ADR is the absorbed dose rate in air in nGy/h, 0.7 (SvGy) is the conversion factor for absorbed dose rate in air to an effective dose, 0.8 is the indoor occupancy factor while 0.4 is the outdoor occupancy factor. The units of AED are milliSierverts per year (mSv/y).

IV. RESULTS AND DISCUSSIONS

IV.1 DETERMINATION OF ANNUAL EFFECTIVE DOSE

The AED (in) and AED (out) were determined and the results tabulated in Table 2. The results were also represented in Figure 2.

Table 2: A summary of indoor and Outdoor Annual Effective Dose Rates for all the samples in this study.

	Sample	AED (in) mSv/y	AED (out) mSv/y
Field 1	S_1	0.36 ± 0.01	0.24 ± 0.01
	S_2	0.25 ± 0.01	0.17 ± 0.01
	S_3	0.48 ± 0.01	0.32 ± 0.01
	S_4	0.20 ± 0.01	0.13 ± 0.01
	S_5	0.21 ± 0.01	0.14 ± 0.01
	Average AED	$\mathbf{0.30 \pm 0.01}$	$\mathbf{0.20 \pm 0.01}$
Field 2	S_6	0.23 ± 0.01	0.15 ± 0.01

	Sample	AED (in) mSv/y	AED (out) mSv/y
	S_7	0.16 ± 0.01	0.11 ± 0.01
	S_8	0.18 ± 0.01	0.12 ± 0.01
	S_9	0.22 ± 0.01	0.15 ± 0.01
	S_{10}	0.17 ± 0.01	0.12 ± 0.01
	Average AED	$\mathbf{0.19 \pm 0.01}$	$\mathbf{0.13 \pm 0.01}$
Field 3	S_{11}	0.30 ± 0.01	0.20 ± 0.01
	S_{12}	0.20 ± 0.01	0.13 ± 0.01
	S_{13}	0.17 ± 0.01	0.12 ± 0.01
	S_{14}	0.21 ± 0.01	0.14 ± 0.01
	S_{15}	0.50 ± 0.01	0.33 ± 0.01
	Average AED	$\mathbf{0.28 \pm 0.01}$	$\mathbf{0.18 \pm 0.01}$
Field 4	S_{16}	0.40 ± 0.01	0.27 ± 0.01
	S_{17}	0.27 ± 0.01	0.18 ± 0.01
	Average AED	$\mathbf{0.34 \pm 0.02}$	$\mathbf{0.23 \pm 0.01}$

Source: [11].

From the Table 2, soil samples from field 1 had an average AED (in) of 0.30 ± 0.01 mSv/y and an average AED (out) of 0.20 ± 0.01 mSv/y, an average AED (in) of 0.19 ± 0.01 mSv/y, an average AED (out) of 0.20 ± 0.01 mSv/y for field 2, an average AED (in) of 0.28 ± 0.01 mSv/y and an average AED (out) of 0.18 ± 0.01 mSv/y for field 3 and an average AED (in) of 0.34 ± 0.01 mSv/y and an average AED (out) of 0.23 ± 0.01 mSv/y for field 4. The average AED (in) and average AED (out) for field 4 were higher, this is because although the field had not been used for 2 years, accumulation of the radionuclides had taken place due to continuous use of inorganic fertilizers.

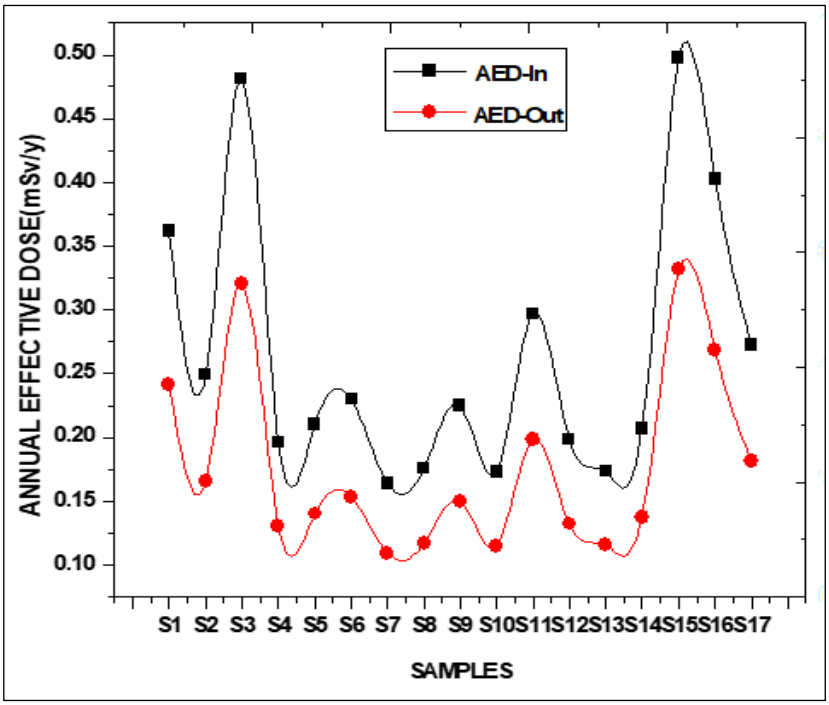


Figure 2: Indoor and Outdoor Annual Effective Doses for the collected samples.
Source: Authors, (2023).

It can be noticed from the results that all the fields had their AED (in) and AED (out) above the world value of 0.07 mSv/y [2]. Although all samples had high AED (in) and AED (out) than the world levels, their values were below the world permissible value of 1 mSv/y.

V. CONCLUSIONS

An investiagation of annual effective dose in the surface soils of Ahero rice fields, Kenya has been done using gamma ray spectroscopy. The average AED (in) and AED (out) values from all the four fields were below the permissible level of 1mSv/y [22]. Thus the interaction of the population with the soils does not pose a health hazard. However, a study needs to be done to assess the AED (in) and AED (out) in the rice components and other crops cultivated at the study area for example Soy beans, maize and water melons to provide a comprehensive data base information on radiation safety.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Mukanda Kere Wanyama, Michael Nakitare Waswa and Linda Ouma.
Methodology: Mukanda Kere Wanyama, Michael Nakitare Waswa.

Investigation: Mukanda Kere Wanyama, Michael Nakitare Waswa.
Discussion of results: Mukanda Kere Wanyama, Michael Nakitare Waswa and Linda Ouma.
Writing – Original Draft: Mukanda Kere Wanyama.
Writing – Review and Editing: Mukanda Kere Wanyama, Michael Nakitare Waswa.
Resources: Linda Ouma.
Supervision: Michael Nakitare Waswa and Linda Ouma.
Approval of the final text: Mukanda Kere Wanyama, Michael Nakitare Waswa and Linda Ouma.

VII. ACKNOWLEDGMENTS

The authors thank the department of Science, Technology and Engineering; Kibabii University, Kenya for providing a conducive environment for the success of this study. The authors also thank NACOSTI for giving them a license to do the research at the study area.

VIII. REFERENCES

[1] Hameed, P. S., Pillai, G. S., &Mathiyarasu, R. (2014). A study on the impact of phosphate fertilizers on the radioactivity profile of cultivated soils in Srirangam (Tamil Nadu, India). *Journal of Radiation Research and Applied Sciences*, *7*(4), 463-471.

[2] United Nations Scientific Committee on the Effects of Atomic Radiation. (2000). *Sources and Effects of Ionizing Radiation, United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 2000 Report, Volume I: Report to the General Assembly, with Scientific Annexes-Sources*. United Nations.

[3] Ribeiro, F. C. A., Silva, J. I. R., Lima, E. S. A., do AmaralSobrinho, N. M. B., Perez, D. V., &Lauria, D. C. (2018). Natural radioactivity in soils of the state of Rio de Janeiro (Brazil): Radiological characterization and relationships to geological formation, soil types and soil properties. *Journal of environmental radioactivity*, *182*, 34-43.

[4] Ugbede, F. O., Osahon, O. D., &Agbalagba, E. O. (2021). Radiological Risk Assessment of 238U, 232 Th and 40 K in Soil and Their Uptake by Rice Cultivated in CAS Paddy Environment of Abakaliki, Nigeria. *Chemistry Africa*, 1-11.

[5] Encabo, R. R., Cruz, P. T. F., Bonga, A. C., DelaSada, C. L., Omandam, V. J., Olivares, J. U., ... & Feliciano, C. P. (2020). Measurement of ambient gamma dose rate in Metro Manila, Philippines, using a portable NaI (TI) scintillation survey meter. *Environmental Monitoring and Assessment*, *192*, 1-9.

[6] Emelue, H. U., Jibiri, N. N., & Eke, B. C. (2014). Excess lifetime cancer risk due to gamma radiation in and around Warri refining and petrochemical company in Niger Delta, Nigeria. *Journal of Advances in Medicine and Medical Research*, 2590-2598.

[7] Raburu, P. O., &Masese, F. O. (2012). Development of a fish-based index of biotic integrity (FIBI) for monitoring riverine ecosystems in the Lake Victoria drainage Basin, Kenya. *River Research and Applications*, *28*(1), 23-38.

[8] Gaafar, I., Elbarbary, M., Sayyed, M. I., Sulieman, A., Tamam, N., Khandaker, M. U., ... & Hanfi, M. Y. (2022). Assessment of Radioactive Materials in Albite Granites from Abu Rusheid and Um Naggat, Central Eastern Desert, Egypt. *Minerals*, *12*(2), 120.

[9] Bray, F., Ferlay, J., Soerjomataram, I., Siegel, R. L., Torre, L. A., &Jemal, A. (2018). Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *CA: a cancer journal for clinicians*, *68*(6), 394-424.

[10] Nahar, A., Asaduzzaman, K., Islam, M. M., Rahman, M. M., & Begum, M. (2018). Assessment of natural radioactivity in rice and their associated population dose estimation. *Radiation Effects and Defects in Solids*, *173*(11-12), 1105-1114.

[11] Mukanda, K. W., Waswa, M. N., & Ouma, L. (2022). Radiological risk assessment of 238U, 232TH and 40K in the top soils of ahero paddy fields of Kisumu county, Kenya. *ITEGAM-JETIA*, *8*(36), 32-36.

[12] United Nations. Scientific Committee on the Effects of Atomic Radiation. (2011). Sources and Effects of Ionizing Radiation: United Nations Scientific Committee on the Effects of Atomic Radiation: UNSCEAR 2008 Report to the General Assembly, with Scientific Annexes (Vol. 2). United Nations Publications.

[13] Ugbede, F. O. (2020). Distribution of 40K, 238U and 232Th and associated radiological risks in River sand sediments across Enugu East, Nigeria. *Environmental Nanotechnology, Monitoring & Management*, *14*, 100317.

[14] Mburu, C., Kinyua, R., Karani, G., & Kiiyukia, C. (2018). Work Related Ill Heath among Farm Workers at Ahero Irrigation Scheme, Kenya. *International Journal of Science and Research*, 2319-7064.

[15] KNBS, K. (2019). Kenya Population and Housing Census Volume I: Population BCounty and Sub-County. *Vol. I*, *2019*.

[16] M'marete, C. K. (1991). *The bearing capacity of the soils of Ahero irrigated rice fields under the exposure to land preparation traffic* (Doctoral dissertation, University of Nairobi).

[17] Ajayi, O. S., & Dike, C. G. (2016). Radiological hazard assessment of natural radionuclides in soils of some oil-producing areas in Nigeria. *Environmental Forensics*, *17*(3), 253-262.

[18] Jibiri, N. N., Alausa, S. K., &Farai, I. P. (2009). Assessment of external and internal doses due to farming in high background radiation areas in old tin mining localities in Jos-plateau, Nigeria. *Radioprotection*, *44*(2), 139-151

[19] Gad, A., Saleh, A., &Khalifa, M. (2019). Assessment of natural radionuclides and related occupational risk in agricultural soil, southeastern Nile Delta, Egypt. *Arabian Journal of Geosciences*, *12*(6), 1-15.

[20] Paquet, F., Bailey, M. R., Leggett, R. W., Lipsztein, J., Marsh, J., Fell, T. P., ...& Harrison, J. D. (2017). ICRP publication 137: occupational intakes of radionuclides: part 3. *Annals of the ICRP*, *46*(3-4), 1-486.

[21] SureshGandhi, M., Ravisankar, R., Rajalakshmi, A., Sivakumar, S., Chandrasekaran, A., &Anand, D. P. (2014). Measurements of natural gamma radiation in beach sediments of north east coast of Tamilnadu, India by gamma ray spectrometry with multivariate statistical approach. *Journal of Radiation Research and Applied Sciences*, *7*(1), 7-17.

[22] Hashim, N. O., Rathore, I. V. S., Kinyua, A. M., & Mustapha, A. O. (2004). Natural and artificial radioactivity levels in sediments along the Kenyan coast. *Radiation physics and chemistry*, *71*(3-4), 805-806.

Journal of Engineering and Technology for Industrial Applications

ISSN ONLINE: 2447-0228

ITEGAM-JETIA

Manaus, v.9 n.44, p. 9-17. Nov/Dec, 2023

DOI: https://doi.org/10.5935/jetia.v9i44.938

RESEARCH ARTICLE OPEN ACCESS

SCALE-UP BY MATHEMATICAL MODELING OF ANAEROBIC REACTORS FOR YEAST WASTEWATER TREATMENT

Gabriel Alejandro Iglesias Barreto*[1] and Iván Leandro Rodríguez Rico[2]

[1] LABIOFAM VC Bioproducts Complex. Santa Clara, Cuba.
[2] Central University "Marta Abreu" of Las Villas. Santa Clara, Cuba.

[1] http://orcid.org/0000-0003-0086-2236, [2] http://orcid.org/0000-0003-1295-5368

Email: *gibarreto00@gmail.com, ivanrrico@gmail.com

ARTICLE INFO

Article History
Received: October 30th, 2023
Revised: December 04th, 2023
Accepted: December 06th, 2023
Published: December 30th, 2023

Keywords:
Anaerobic Digestion,
Process Modeling,
Bioreactors Scale-Up,
Mathematical Simulation.

ABSTRACT

Wastewater treatment by anaerobic digestion is a viable solution for the discharge of industrial liquid wastes with different levels of contamination. The kinetics of the anaerobic digestion reaction, in laboratory tubular reactors, by a consortium of microorganisms to treat liquid waste from a feed yeast industry does not adjust to a Monod equation, but to a numerical adjustment carried out with the Table Curve 2D program. Where 0.65 d^{-1} was determined as the maximum cell growth rate and other parameters of the microbial kinetics. The error with which the selected model describes the experimental results is ± 24 mg/L. The mathematical analysis of the models used was carried out in MATLAB® software, which allowed the determination of a novel dimensionless number, named Gai, which facilitated the analysis, scaling by mathematical modeling and dimensioning of the anaerobic reactors at industrial scale for the treatment of 430 m^3/d of waste. Tubular bioreactors with a total height of 18,93 m and 2,4 m in diameter were dimensioned. The required flow rate of 2,91 m/h was also determined. The Gai number is a relationship between the governing phenomena of the studied process, the conversion and residence time constants, with two main mechanisms involved in the process: convective flow and conversion. Once it has been demonstrated that there are no diffusional restrictions in the anaerobic leaf.

I. INTRODUCTION

The context of research and technological innovations for process industry does not escape from problems involved in converting the results achieved in the laboratory into a safe and economically feasible structure for industrial scale-up. The scale-up of chemical operations represents significant challenges in terms of the economic management of the inputs involved and the acquisition of the necessary equipment, which are very different from the resources and techniques used in the laboratory for the same purpose [1] and [2]. Scaling becomes an important factor for the insertion of new production technologies originating from laboratory-scale research, which, in order to find an advantageous position in the industry, must overcome the uncertainties that arise with the change of production scale and, even if these obstacles are overcome, they do not ensure the success of an industrial plant without first developing the studies corresponding to the economic and commercial profile, the environmental impact of the proposed installation and the real availability of the materials necessary to carry out and sustain the manufacturing activity over time.

Mathematical simulation of processes is a highly effective tool for the analysis of real systems described by mathematical models obtained and validated for the description of the phenomena studied. This tool makes it possible to evaluate the behavior of the system under study. The degree of specificity and robustness of the response offered by the mathematical model depends on the rigor with which the researcher has developed it [1-3]. A great advantage of mathematical models is that it's are a very valuable tool when you want to observe the behavior of a system, but are unwilling or unable to experiment with scaling equipment,

particularly with reactors, because of the implications for process safety and feasibility [2] and [3]. Mathematical modeling is a powerful tool that can be used to understand and predict the behavior of biological systems. In the case of biological reactions, mathematical modeling can be used to describe cell growth, chemical production, and substrate degradation [4]. Mathematical models of biological reactions are usually systems of differential equations that describe the evolution of reactant and product concentrations over time. These models can be used to study the effect of factors such as temperature, nutrient concentration and the presence of inhibitors on reaction behavior. Mathematical modeling has a number of proven advantages over traditional experimental methods for studying biological reactions [5-7]. The development of mathematical models for industrial microbiological processes is an active field of research. The development of useful mathematical models must take into account factors specific to biological reactions involving microbial growth and the dependence of this multiplication on pH, temperature and nutrient availability. [8] Industrial microbiological processes usually take place in heterogeneous systems, where physical and chemical conditions may vary in space and time. The mathematical model must take this heterogeneity into account in order to faithfully predict the behavior of the process at a change of scale.

Bioreactor scale-up is a complex process that requires the consideration of a number of criteria and techniques to ensure the reproduction of microbiological reactions in industry or pilot plant scale equipment, performed and stabilized in the laboratory environment. Kossen [9] reports the fundamental methods for bioreactor scale-up with current application [10] and [11]: the fundamental method (solution of microbalances for mass, heat and momentum transfer), the semi-fundamental method (solution of simplified balances), the approximate calculation (known as rule of thumb), the trial and error with iterations and the scale-up by dimensional analysis. Dimensional analysis is a technique that performs the mathematical adjustments to vary the operating parameters at different scales in such a way that the most significant dimensionless groups or models remain unchanged when passing from one stage to another of the scaling. The physical significance of these groups is a ratio of time constants for the different mechanisms involved ensuring that the relative significance of the mechanisms does not change with increasing equipment size. This method is very efficient, but has limitations such as the impossibility of maintaining constant all the dimensionless groups, therefore, the most transcendental ones must be determined and the rest must be ignored as a result of the regime analysis. The criteria for scaling biological reactors can be divided into two main categories: physical criteria referring to the physical parameters linked to the reactor properties and operating variables, and biological criteria associated with the properties of the microbial culture used, its stability and reaction kinetics [12] and [13]. For bioreactors scale-up the most commonly used criteria are: reactor geometry, oxygen transfer coefficient if the reaction is aerobic (kLa), maximum exertion, power per unit volume (P/V), gas volumetric flow per unit volume of liquid (vvm) and gas surface velocity [14]. Current trends for the scale-up of tubular reactors for anaerobic digestion and biogas production focus on the development of larger and more efficient reactors [15]. In terms of size, larger capacity tubular reactors allow increasing biogas production and reducing investment costs. On the other hand, raising the efficiency of anaerobic digestion operation of liquid waste is focused on research and continuous improvement of mass and heat transfer mechanisms to increase biogas productivity and purification. Successful scale-up of biological reactors is essential for the development of the modern transformative process industry, committed to responsible environmental management and economically feasible [16].

The treatment of wastewater with biological processes, such as anaerobic digestion, is a viable solution to the discharge of liquid waste with different levels of chemical and biological contamination, while generating a highly valuable product from the energy point of view, biogas. The present research deal with the wastewater treatment of a feed yeast factory for animal feed, adjusting the strategy outlined for the management of liquid waste with the requirements for discharge into the environment stipulated by NC 27:2012 [17]. Liquid effluents from similar industries include the cleaning water from the installed equipment and the residue from the fermentation process. These residuals as described by Figueroa [18] present high concentrations of dissolved organic matter, nitrogen and phosphorus and a chemical oxygen demand (COD) between 50 and 20 000 mg/L. It is extremely important that these wastewaters are adequately treated before discharge into the environment to minimize their ecological impact. In order to design a system for wastewater management, process simulation tools are used; starting from laboratory scale experiences emulating the removal of COD from liquid waste by anaerobic digestion (producing biogas as a highly valuable by-product due to its energetic power) of settled sludge in treatment plants of similar industries. Biogas generation brings economic attractiveness to industrial waste management, being possible its capture, treatment and distribution for domestic or industrial use as a substitute for liquefied petroleum gas according to technologies proposed by [19] and [20]. The mathematical models obtained and validated for the anaerobic digestion carried out in the laboratory bioreactors allow evaluating the possibilities of scaling up the process to pilot and industrial plant scale dimensions. The mathematical simulation incorporates solid criteria for the design of the proposed technology, allowing to evaluate the behavior of the system under variation of operational and constructive parameters that provide valuable data for the management of the project from its conceptualization.

Obtaining the mathematical model and parameters for the simulation of the yeast plant wastewater treatment process aims to establish a methodology for scaling this operation safely and accurately with the use of computational utilities; expanding the opportunities for the development of similar technologies with the combination of methods for reactor scaling.

The main objective of this research is the study at laboratory scale of the removal of contaminants in wastewater from a feed yeast industry by anaerobic digestion in tubular bioreactors and the scaling of the same maintaining geometric similarity and using mathematical modeling, for the dimensioning of the reactors at industrial scale.

As an important result of the geometric similarity scaling and mathematical modeling of anaerobic bioreactors for the treatment of wastewater from the production of feed yeast, a dimensionless number is deduced for the system studied. This dimensionless group facilitates the analysis, scaling and dimensioning of anaerobic reactors on an industrial scale.

II. MATERIALS AND METHODS

II.1 LABORATORY STUDIES

The data necessary for the scaling of the biological treatment studied are based on a laboratory-scale study of COD removal. The treatment is carried out by a microbial consortium of sludge extracted from a wastewater treatment plant. The studies

were carried out in reactors that can be considered hybrids since they combine characteristics of traditional UASB reactors and tubular reactors [20] and [21]. For the study of the anaerobic digestion of the yeast production plant waste, a system of two tubular reactors connected in series with possibilities for axial sampling and between both reactors is used.

The treated fluid is pumped by a Masterflex L/S 7535-04 multichannel peristaltic pump with low pressure and constant flow rate of 595 ml/min based on preliminary studies by [22]. Figure 1 graphically depicts the components of the study system. The selected tubular reactors consist of two high-density polyethylene (HDPE) plastic pipes with 1,50 m length each for a total height of 3,00 m and inner diameter equal to 0,38 m; the thickness of the pipes is 2,0 mm. The selection of these materials is made according to the fluid and flow to be treated, which has a viscosity close to water's at normal temperature and pressure. To support the microbial population used for the anaerobic digestion of the waste, non-degradable commercial plastic rope, sterilized by boiling in water, was used. The filler was arranged longitudinally, occupying the inner volume of the reactor body, offering support to the microorganisms and hydraulic resistance to the flow.

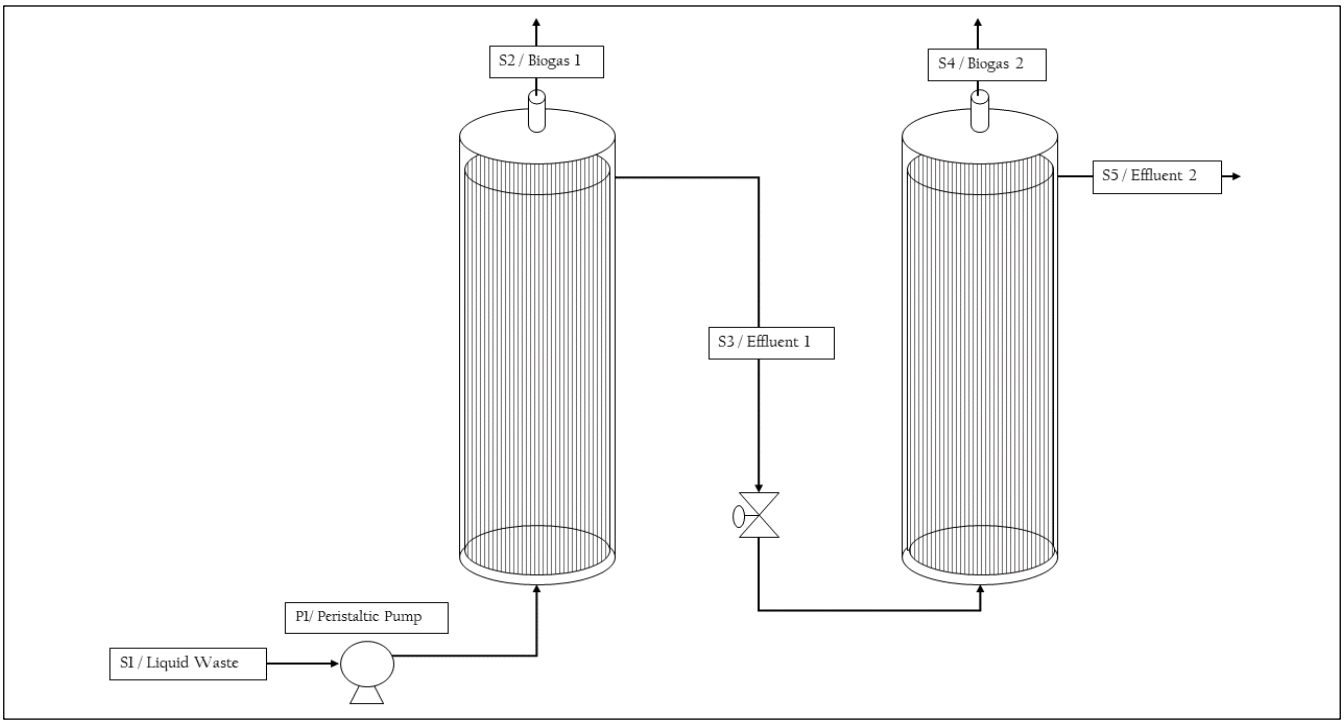


Figure 1: Schematic bioreactors used at the laboratory scale.
Source: Authors, (2023).

For the kinetic study of the microbiological reaction that develops, the measurement of COD depletion and the increase in the presence of volatile suspended solids (VSS) is proposed according to the experimental methodology described in [23]. These parameters are associated with the progress of wastewater remediation and cell biomass growth in the treatment medium respectively. On the other hand, the increase in the concentration of biogas generated, according to the technique referred to in Fernandez [24], indicates the production of this compound and allows estimating the efficiency of this treatment for its subsequent scaling up. For the measurements, multiple samples were taken along the reactors and at the exit of the first one with periods of three days of reaction until completing 45 days. The experimentally obtained data were mathematically adjusted with Table Curve 2D software [25].

II.2 MATHEMATICAL MODELLING AND SIMULATION OF THE ANAEROBIC PROCESS

The reaction yield parameter is studied as a function of the ratio biomass(X)/substrate(S) according to equation (1).

$$Y_{X/S} = -\frac{\Delta X}{\Delta S} = \frac{X_1 - X_0}{S_0 - S_1} \quad (1)$$

Instead, the cell growth rate (μ) is investigated following the relationship X=f(t) reported by the graph plotted in Table Curve 2D. The derivative of the expression fitted and evaluated for the different experimental time intervals responds then to the μ of the studied system according to equation (2).

$$\mu = \frac{1}{X}\frac{dX}{dt} \quad (2)$$

We then proceed according to the Lineweaver-Burk method applied by [26] for the linearization of the cell growth data with the Monod equation. Another usable alternative is the numerical adjustment of the data obtained from μ versus S. For this purpose, the Table Curve 2D modeling tool is used, which presents the adjustment of the experimental data with a bank of mathematical expressions in pursuit of the best possible fit to the behavior of the μ variable.

In order to choose among the models for the selection of the most adequate one as a response to the microbial kinetics of the reaction, the criterion proposed by [14] and [27] is followed. The equation that best reflects the process is the one that, when used in the simulation of the process, according to the mathematical model of a tubular reactor, produces the smallest deviations with respect to the experimental values. The deviations are estimated as the

quotient between the square of the difference between the experimental value and the magnitude calculated by the model and the square of the experimental value for each variable as expressed in equation (3). Although this deviation is determined for the variables substrate concentration, biomass and an overall deviation, the behavior of the substrate concentration variable is of special attention, since the objective of the process is the decontamination of the residual.

$$\varepsilon = \frac{\left(X_{exp} - X_{cal}\right)^2}{X_{exp}{}^2} \quad (3)$$

To validate the selected mathematical model corresponding to the cellular kinetics of the process, the function obtained is subjected to mathematical analysis criteria. Starting with the domain analysis and physical restrictions, sign analysis, monotony and concavity of the same starting from the sign analysis of the first and second derivatives. The maximum velocity value is an important parameter in the study of kinetics, in addition to the fact that it can be contrasted with the data documented in Dunn [28] to classify the biological composition of the microbial population used in the experiment.

The substrate removal at laboratory scale responds to equation (4) studied by [29] and [30], where the parameter μ is replaced by the mathematical model obtained according to the methodology of section II.2. Where the term γ includes properties of the bioleaf and microbial growth, remaining approximately constant at 10 409 mg/L, with variations in the flow rate to be treated [14]. This value of γ is considered small, since much higher biomass concentrations in bioleafs are reported up to 20 000 mg/L as documented in [28]. The variable v responds to the flow rate, μ the selected expression of cell growth rate and the calculated Yx/s yield.

$$\frac{dS}{dZ} = -\frac{1}{v} \cdot \frac{\mu}{Y_{X/S}} \cdot \Upsilon \quad (4)$$

The mathematical development of this expression as a function of the growth rate equation for substrate variations can be simulated in the MATLAB® software suite [31] to inspect the progress of the reaction with respect to the length of the reactors for different diameters and thus multiple length/diameter ratios of the reactors. At larger than laboratory scale in either pilot or industrial plants it is necessary to include the effectiveness factor (equation 5) in the expression (4) for substrate removal.

$$\eta = \frac{r_{S\,cal}}{r_s} \quad (5)$$

Based on these considerations, equation (6) can be used as a mathematical model for substrate removal, taking z as the useful height of the reactor, the expression of the effectiveness can be evaluated for flow rate values that cause a decrease in DOC from a value S_0 to a value S measured experimentally.

$$\eta = \frac{\int_{S_0}^{S} \frac{dS}{\mu}}{\Upsilon \cdot z} \cdot v \cdot Y_{\frac{X}{S}} \quad (6)$$

II.3 PROCESS SCALING

With the interest of scaling up the process to industrial plant dimensions, a methodology is proposed to design biological reactors for the anaerobic digestion of 430 m^3/d of the wastewater from the feed yeast industry, where the levels of COD removal and biogas production obtained at laboratory scale can be reached.

For the scale-up from the laboratory to an industrial scale, the geometric similarity between both scales and mathematical modeling are used, based on a dimensionless number developed during the research. Taking into account the geometrical similarity of the reactors, based on the ratio length/diameter (L/D) of the laboratory reactors equal to 7,89, it is possible to estimate the dimensions of a reactor for the treatment of this type of waste with a waste volume 490 times higher than the one installed on a small scale according to equation (7).

$$V = \frac{\Pi \cdot D^2}{4} \cdot L \quad (7)$$

The mathematical model developed relates the dimensionless number and the removal of S, a fundamental aspect for sizing the industrial equipment for wastewater remediation.

The simulation with the mathematical models and the estimation of the error, facilitate the validation of the results to be obtained, offering a methodology for the calculation of the design dimensions of the anaerobic digestion reactors.

III. RESULTS AND DISCUSSIONS

III.1 MATHEMATICAL MODELATION AND SIMULATION

The experimental data were plotted using Table Curve 2D software, the graphs obtained are shown in the following Figures where the behavior of the parameters COD, VSS and biogas production with time progress is verified. Figure 2 describes the drop of COD with the progress of the anaerobic digestion in the laboratory where it can be seen that after 25 days of reaction, the demand remains practically unchanged asymptotically for more than 2 000 mgO_2/L of treated effluent.

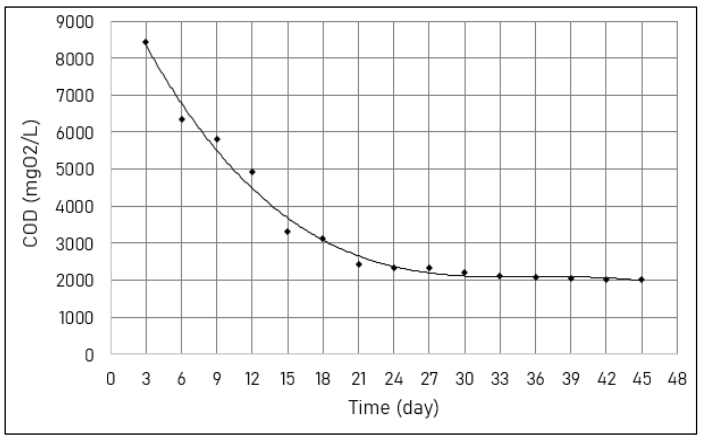


Figure 2: COD variation over time.
Source: Authors, (2023).

Figure 3 shows the appearance of volatile suspended solids with advancing reaction time associated with cell multiplication which is interpreted as exponentially increasing over the entire domain of the experiments performed for a practically constant Yx/s yield of 0,18. These data are in agreement with previous studies performed by Simeonov [32].

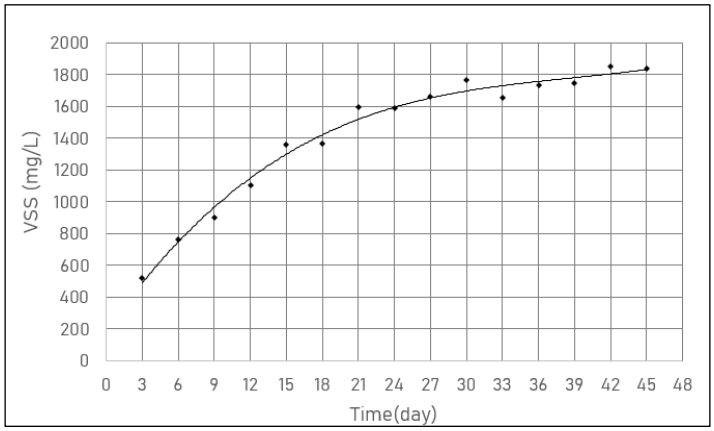


Figure 3: VSS variation over time.
Source: Authors, (2023).

The production of biogas as a high value-added co-product of anaerobic digestion of liquid waste is shown in Figure 4 with the increase in biogas concentration as the reaction time progresses. This behavior shows promising results in terms of the selected technological alternative generating 3 600 mg of biogas per liter of treated liquid for a reaction time of 21 days, obtaining a maximum production in the order of 5 400 mg/L for a final time of 45 days of digestion. The biomass production yield calculated according to equation 1 resulted in an almost constant value of 0,18, consistent with the specialized literature published in [33] for similar studies.

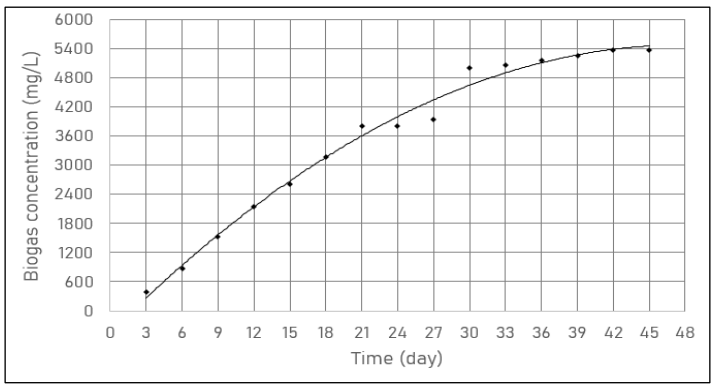


Figure 4: Biogas concentration over time.
Source: Authors, (2023).

The adjustment of the experimental data for cell growth according to the Monod equation is shown in Figure 5. It is observed that the microbial development of the studied population does not fit the Lineweaver-Burk linearization technique.

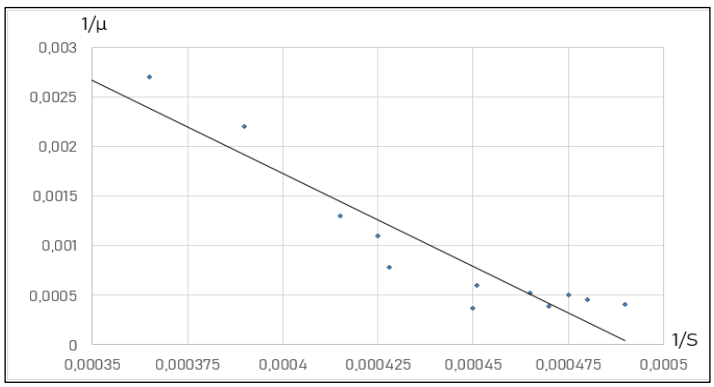


Figure 5: Lineweaver-Burk linearization.
Source: Authors, (2023).

Therefore, for the modeling of this process a numerical adjustment of the variable μ and the depletion of S is explored with the Table Curve 2D tabulator tool, obtaining among others the expressions related in Table 1.

Table 1: Numerical adjustments of μ=f(S).

Table Curve 2D equation	Equation	Parameters	R^2
80	$\mu = \left(a + \frac{b}{S}\right)^2$	b = -1158,82 a = 0,529	0,97
78	$\mu = \left(a + \frac{b}{\sqrt{S}}\right)^2$	b = -36,37 a = 0,798	0,954
38	$\mu = \exp\left(a + \frac{b}{S}\right)$	b = -11118,68 a = -0,429	0,98
39	$\mu = \exp\left(a + \frac{b}{S^{1,5}}\right)$	b = -497660,34 a = -1,139	0,96

Source: Authors, (2023).

Following the criteria for the selection of the kinetic model exposed in section II.2, the expression 38 of Table 1 whose coefficient of determination adjusts for 98% being superior to the rest of the expressions. The graphical performance of this equation and its contrast with the experimental measurements is shown in Figure 6.

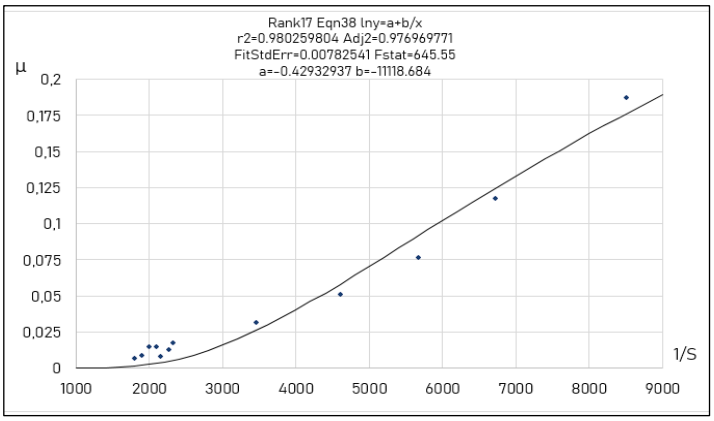


Figure 6: Cell growth rate versus substrate depletion.
Source: Authors, (2023).

The domain of expression chosen for the description of cell growth kinetics is all positive non-zero real substrate concentration S values. This mathematical restriction obeys the logic that it does not make sense to assume values of S less than or equal to zero since the amount of substrate to be administered to the biological system is not determined by negative or zero values, leaving the equation undefined for these values. On the other hand, the behavior of too small substrate concentration values closes to the proximity of zero is analyzed by applying the limit criterion for the independent variable S. In this case, given the restriction imposed S>0, only the case described in equation (8) is of interest. The result is logical and indicates that as the substrate is depleted the rate of reaction slows down until it stops.

$$\lim_{S \to 0} \exp\left(a + \frac{b}{S}\right) = 0 \tag{8}$$

On the other hand, the behavior when the substrate concentration is much higher approaching infinity indicates the existence of a possible horizontal asymptote that responds to the linear equation y=mS+b, defined in equation (9) whose intercept with the axis of the ordinates in the b parameter.

$$m = \lim_{S \to +\infty} \frac{\exp\left(a + \frac{b}{S}\right)}{S} = 0 \quad (9)$$

$$b = \lim_{S \to -\infty} \left(exp\left(a + \frac{b}{S}\right) - 0 \cdot S\right) = \exp a \quad (10)$$

These results verify that the cell growth equation presents a horizontal asymptote (equation 10) for when S is in excess, μ tends to the value of 0.65 d^{-1}, as the reaction rate will not increase after this value is considered the same as the maximum growth rate of this biological system (μ_{max}) calculated in (11).

$$y = \exp(-0{,}429) = 0{,}65 \quad (11)$$

The analysis of the sign of the function indicates that μ>0 for all values of S defined in the previous analysis. The first derivative of the function indicates that μ is increasing throughout its domain since b is always less than zero and therefore, there is no change in the sign of the first derivative around this point. The second derivative reports that at the point for S equal to half the parameter b, the function has a change of concavity from convex to concave. Indicating that the slope of the curve increases progressively and then begins to decrease corroborating the asymptotic behavior at μ_{max}. The value of b can be taken as an indicator of the affinity. For a lower modular value of b, the change in concavity would occur faster and therefore indicates that the microorganisms would consume the substrate better. Based on the above demonstrations it is convenient to express the kinetics of cell growth according to equation (12).

$$\mu = 0.65 exp\left(\frac{-11118{,}68}{S}\right) \quad (12)$$

Where a = 0,65 d^{-1} which is interpreted as the maximum value that μ can reach; b=-11118,68 mg/L; μ_{max}=0,65d^{-1}. This maximum growth rate value is between the values of μmax reported for populations of methanogenic and acidogenic microorganisms reported by [28], although it is not specifically that of either of these two groups, which is due to the fact that a mixed population of digesting microorganisms is being analyzed.

The computational tools used to explore the mathematical model obtained for the dimensioning of the bioreactors offer conclusive results for the experiences studied. It provides the calculations of diameter and length of the bioreactor vessels at laboratory and pilot plant scale, reporting 0,40 m and 1,03 m in diameter; on the other hand, the calculated heights were 2,56 m and 4,96 m for each scale, respectively. We proceeded to the simulation of this model to determine the accuracy with which it describes the process at laboratory scale, summarizing in Figure 7 the results plotted by the MATLAB® software for different flows of the wastewater to be treated, linked to possible relations of the reactor dimensions if this parameter were kept fixed or depending on the availability of the materials to be accessed in future experiments. The error with which the studied model describes the experimental results at this scale of work is ± 24 mg/L being acceptable.

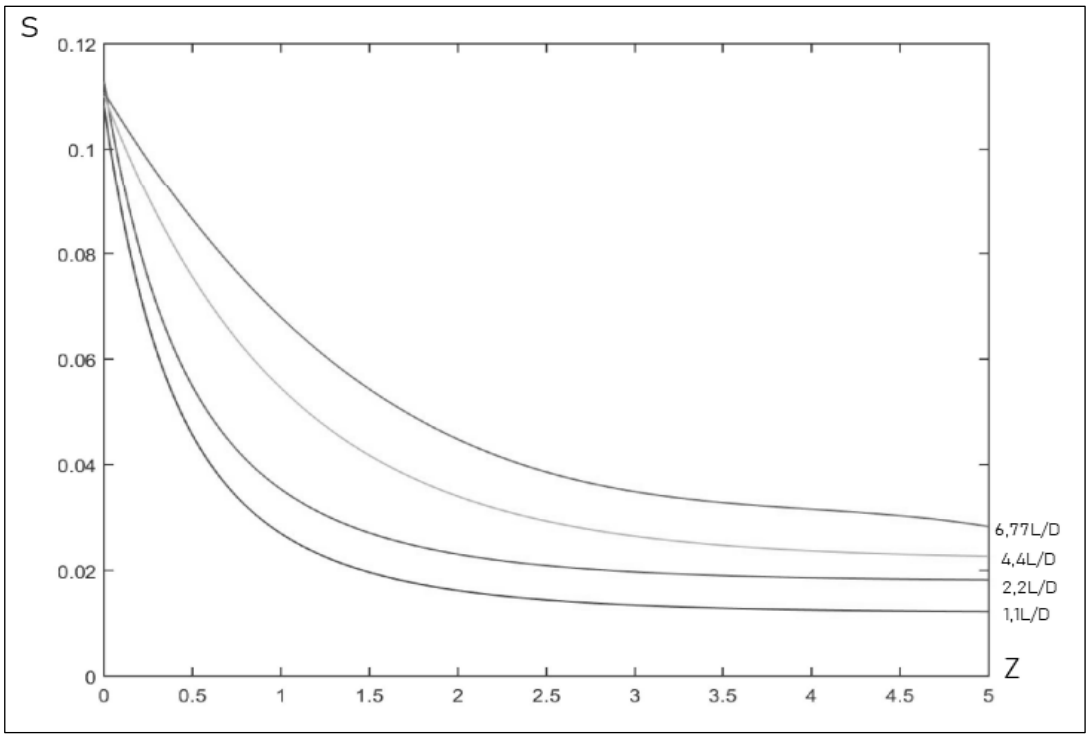


Figure 7: Mathematical simulation of substrate depletion as a function of reactor length.
Source: Authors, (2023).

The modeling at Pilot Plant scale was performed using the mathematical considerations and expressions developed in section II.2 and the results are shown in Figure 7. It shows that the removal effectiveness parameter described in equation (13) is a non-unitary variable, which indicates that the interactions (in this case linked to convective transport) between cell metabolism and physical transport within the reactor are significant. The software provided the mathematical model (equation 14) that describes the relationship of the removal effectiveness and the volumetric flow rate to be treated at the pilot scale.

$$\eta = a + b \cdot v^{0{,}15} \quad (13)$$

Where, a is a dimensionless constant equal to 0,15 and b equal to 0,359 m/volume unit.

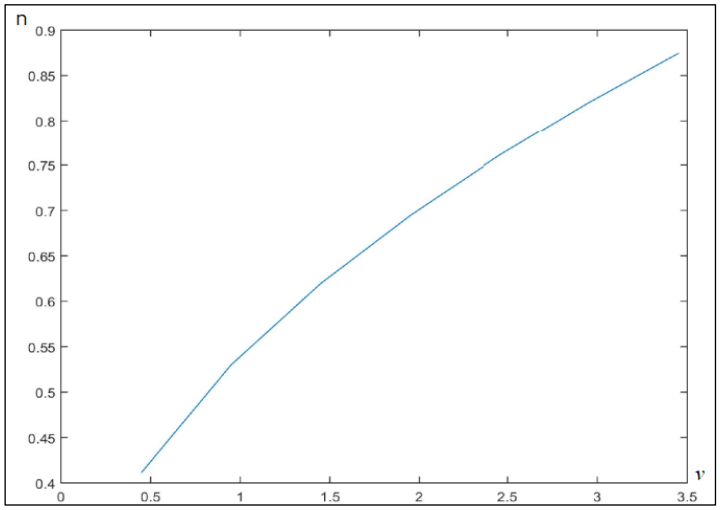


Figure 8: Removal operation effectiveness versus volumetric flow rate.
Source: Authors, (2023).

The removal of DOC in the pilot scale is proposed according to the mathematical development according to equation (14) with an estimated error of ± 71,91 mg/L, admissible according to the projected flow rates and the provisions of NC 27:2012 [4].

$$\frac{dS}{dz} = -\frac{1}{v} \cdot \frac{\mu \cdot Y}{Y_{X/S}} (a + b \cdot v^{0.5}) \quad (14)$$

III.2 PROCESS SCALE-UP

By rewriting the previous mathematical model, complying with mathematical considerations (15), (16) and (17) and integrating it to equation (14), the expression (18) is obtained, which corresponds to the dimensionless model of the process at pilot plant scale.

$$S^* = \frac{S}{S_0} \quad (15)$$

$$z^* = \frac{z}{L} \quad (16)$$

$$\varepsilon = \frac{\mu \cdot Y}{Y_{X/S}} \cdot (a + b \cdot v^{0,5}) \quad (17)$$

$$-\frac{v \cdot S_0}{L \cdot \varepsilon} \frac{dS^*}{dz^*} - \exp\left(\frac{\mu_2}{S_0 \cdot S^*}\right) = 0 \quad (18)$$

From this mathematical arrangement it is very interesting to obtain the dimensionless group (expression 19) on which the solution of the scaling problem depends and which is no more than a relation between the conversion and residence time constants. It thus reflects the two mechanisms involved in the process: convective flow and conversion, once it has been shown that there are no diffusional restrictions in the anaerobic leaf. This group is similar to the D/uL dispersion modulus, although the relationship between linear velocity (v) and maximum reactor length (L) is not directly proportional. This group presents specific parameters of the particular process under study, all of which makes it approximate a dimensionless modified Damköhler number assigned the name Gai (19). The laboratory reactor presents a Gai=0,101 which depends, as shown in (19), on the flow rate (v), the length of the reactor (L), the initial substrate concentration (S0) and the array ε enclosing the parameters of the kinetics of the cell reaction unwrapped and the removal effectiveness of the equipment.

$$Gai = \frac{v \cdot S_0}{L \cdot \varepsilon} \quad (19)$$

The development of this dimensionless number is extremely useful to accomplish the scaling of the system studied in the laboratory (subscript s) described in section II.1. The small model was used to treat 0,858 m^3/day of wastewater however, it is necessary to design a larger scale equipment (subscript L) similar to guarantee the treatment of the waste in a satisfactory operation. To assure this similarity, the length and diameter of a geometrically equal reactor (expression 20) capable of assimilating up to 430 m^3/day of the waste generated is calculated.

$$\frac{L_s}{D_s} = \frac{L_L}{D_L} = 7{,}89 \quad (20)$$

Where: s-small reactor and L- large reactor.

The solution of equation (7) considering the constraint (20) for the new volumetric flow rate leads to the dimensioning of the larger reactor with a height of 18,93 m (with an arrangement similar to the laboratory system analyzed, of two 9,46 m tubular reactors in series) and 2,4 m in diameter. Then the dimensionless group Gai must remain constant for both scales ensuring that the controlling mechanisms of the process remain the same at both scales by varying v, given the increase of the total length of the reactor and volumetric flow of influent to be received. Setting Gai=0,101 and clearing from (19) we obtain that v=2,91 m/h using the facilities of the MATLAB® mathematical package. The influence of the Gai number on substrate removal is shown in Figure 9, obtained by mathematical simulation also in the MATLAB® program.

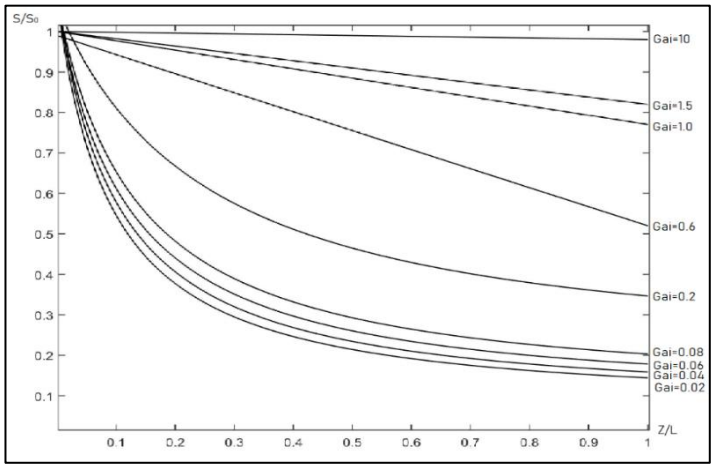


Figure 9: Influence of dimensionless number Gai on substrate removal for different lengths.
Source: Authors, (2023).

IV. CONCLUSIONS

The developed research concludes with a methodology that allows describing the anaerobic digestion of wastewater from a fodder yeast production plant. The adjustment with Table Curve 2D software and the mathematical analysis of the cell growth equation allowed the classification of the microbial population studied, characterized as a mixed culture of methanogenic and

acidogenic microorganisms. The maximum growth rate was estimated at 0,65 d^{-1} and the biomass/substrate productivity at 0,18. The resulting model has a deviation of no more than ±24 mg/L for the calculation of the cell growth rate with respect to the analytical determinations at laboratory scale. Mathematical analysis of the models with MATLAB® software led to a new dimensionless number, named Gai, ($Gai = \frac{v \cdot S_0}{L \cdot \varepsilon}$), similar to the dispersion modulus D/uL. Its development facilitated the analysis, scaling by mathematical modeling and dimensioning of industrial-scale anaerobic reactors. This group approximates a dimensionless modified Damköhler number. For the scaling, the geometric similarity (L/D) between the scales and the constancy of the dimensionless group Gai=0,101 was ensured ensuring the constancy of the reaction controlling mechanisms and the flow regime. As a result of the scaling, industrial tubular bioreactors were dimensioned in series to process a flow rate of 430 m^3/d with a total height of 18,93 m and 2,4 m diameter. The required flow speed equal to 2,91 m/h, was also determined.

V. AUTHOR'S CONTRIBUTION

Conceptualization: Iván Leandro Rodríguez Rico.
Methodology: Gabriel Alejandro Iglesias Barreto and Iván Leandro Rodríguez Rico.
Investigation: Gabriel Alejandro Iglesias Barreto and Iván Leandro Rodríguez Rico.
Discussion of results: Gabriel Alejandro Iglesias Barreto and Iván Leandro Rodríguez Rico.
Writing – Original Draft: Gabriel Alejandro Iglesias Rodríguez.
Writing – Review and Editing: Iván Leandro Rodríguez Rico.
Supervision: Iván Leandro Rodríguez Rico.
Approval of the final text: Iván Leandro Rodríguez Rico.

VI. ACKNOWLEDGMENTS

Acknowledments to Chemical and Pharmacy Faculty of Central University "Marta Abreu"of Las Villas, Cuba.

VII. REFERENCES

[1] R. Cortés Martínez, F. Ramos Miranda, J. E. Miño Valdés, O. Pérez Navarro y E. González Suárez, "Modelación y simulación de procesos en la intensificación de instalaciones de la industria química", *+Ingenio*, Jul - Dic 2020 V2 N2, pp. 22–36, febrero de 2021. [Online]. https://doi.org/10.36995/j.masingenio.2021.02.02.002

[2] M. J. Wade, "Not just numbers: Mathematical modelling and its contribution to anaerobic digestion processes", *Processes*, vol. 8, n.º 8, p. 888, julio de 2020. Accessed: Oct. 11 2023. Aviable: https://doi.org/10.3390/pr8080888

[3] F. A. Ortega Quintana, H. Álvarez y H. A. Botero Castro, "Enfrentando el modelado de bioprocesos: Una revisión de las metodologías de modelado", *Rev. ION*, vol. 30, n.º 1, pp. 73–90, junio de 2017. Accessed Oct. 11 2023. [Online]. Aviable: https://doi.org/10.18273/revion.v30n1-2017006

[4] S. Emebu, J. Pecha y D. Janáčová, "Review on anaerobic digestion models: Model classification & elaboration of process phenomena", *Renewable Sustain. Energy Rev.*, vol. 160, p. 112288, mayo de 2022. [Online]. Aviable: https://doi.org/10.1016/j.rser.2022.112288

[5] A. Basile *et al.*, "Modelling of microbial interactions in anaerobic digestion: From black to glass box", *Current Opinion Microbiol.*, vol. 75, p. 102363, octubre de 2023. Accessed Oct 19 2023. [Online]. Aviable: https://doi.org/10.1016/j.mib.2023.102363

[6] Z. Barahmand y G. Samarakoon, "Anaerobic digestion process modeling under uncertainty: A narrative review", *Int. J. Energy Prod. Manage.*, vol. 8, n.º 1, pp. 41–54, marzo de 2023. [Online]. Aviable: https://doi.org/10.18280/ijepm.080106

[7] S. S. Hosseini y J. F. M. Denayer, "Biogas upgrading by adsorption processes: Mathematical modeling, simulation and optimization approach – A review", *J. Environmental Chem. Eng.*, vol. 10, n.º 3, p. 107483, junio de 2022. [Online]. Aviable: https://doi.org/10.1016/j.jece.2022.107483

[8] L. E. Solís Granda, "Modelación matemática del tratamiento anaerobio de aguas residuales urbanas para la hacienda teresita, sector agrícola de milagro", Tesis de maestría, Univ. Estatal Milagro, Guayas, 2022. [Online]. Aviable: http://repositorio.unemi.edu.ec/handle/123456789/6050

[9] N. W. F. Kossen, "Scale-up in Biotechnology", en *Recent Advances in Biotechnology*. Dordrecht: Springer Neth., 1992, pp. 147–182. Accessed Oct. 19 2023. [Online]. Aviable: https://doi.org/10.1007/978-94-011-2468-3_7

[10] N. Mahendrasinh Kosamia, M. Samavi, K. Piok y S. Kumar Rakshit, "Perspectives for scale up of biorefineries using biochemical conversion pathways: Technology status, techno-economic, and sustainable approaches", *Fuel*, vol. 324, p. 124532, septiembre de 2022. Accessed Oct. 19 2023. [Online]. Aviable: https://doi.org/10.1016/j.fuel.2022.124532

[11] L. C. Moreira, P. O. Borges, R. M. Cavalcante y A. F. Young, "Simulation and economic evaluation of process alternatives for biogas production and purification from sugarcane vinasse", *Renewable Sustain. Energy Rev.*, vol. 163, p. 112532, julio de 2022. Accessed Oct. 19 2023. [Online]. Aviable: https://doi.org/10.1016/j.rser.2022.112532

[12] Y.-H. Du, M.-Y. Wang, L.-H. Yang, L.-L. Tong, D.-S. Guo y X.-J. Ji, "Optimization and Scale-Up of Fermentation Processes Driven by Models", *Bioengineering*, vol. 9, n.º 9, p. 473, septiembre de 2022. Accessed Oct. 19 2023. [Online]. Aviable: https://doi.org/10.3390/bioengineering9090473

[13] G. Wang, C. Haringa, H. Noorman, J. Chu y Y. Zhuang, "Developing a Computational Framework To Advance Bioprocess Scale-Up", *Trends Biotechnol.*, vol. 38, n.º 8, pp. 846–856, agosto de 2020. Accessed Oct. 19 2023. [Online]. Aviable: https://doi.org/10.1016/j.tibtech.2020.01.009

[14] I. Rodríguez y G. Blázquez, *Escalado de reactores químicos y biológicos.* Granada: UGR, 2010.

[15] J. Xia, G. Wang, M. Fan, M. Chen, Z. Wang y Y. Zhuang, "Understanding the scale-up of fermentation processes from the viewpoint of the flow field in bioreactors and the physiological response of strains", *Chin. J. Chem. Eng.*, diciembre de 2020. Accessed Oct. 19 2023. [Online]. Aviable: https://doi.org/10.1016/j.cjche.2020.12.004

[16] S. J. Allan, P. A. De Bank y M. J. Ellis, "Bioprocess Design Considerations for Cultured Meat Production With a Focus on the Expansion Bioreactor", *Frontiers Sustain. Food Syst.*, vol. 3, junio de 2019. Accessed Oct. 19 2023. [Online]. Aviable: https://doi.org/10.3389/fsufs.2019.00044

[17] *Vertimiento de aguas residuales a las aguas terrestres y al alcantarillado — especificaciones*, NC 27: 2012, Organismo Nacional de Normalización de la República de Cuba, La Habana, 2012.

[18] M. Figueroa, O. Pérez, L. Zumalacárregui y A. Cruz, "Evaluación económica de la producción de levadura torula a partir de balances en secciones de la planta", *Rev. Cent. Azucar*, vol. 49, n.º 3, pp. 90–99, 2022. Accessed el 22 de octubre de 2023. [Online]. Aviable: http://centroazucar.uclv.edu.cu/index.php/centro_azucar/article/view/717

[19] A. Mishra, M. Kumar, N. S. Bolan, A. Kapley, R. Kumar y L. Singh, "Multidimensional approaches of biogas production and up-gradation: Opportunities and challenges", *Bioresource Technol.*, vol. 338, p. 125514, octubre de 2021. Accessed Oct. 11 2023. [Online]. Aviable: https://doi.org/10.1016/j.biortech.2021.125514

[20] A. Kasinath *et al.*, "Biomass in biogas production: Pretreatment and codigestion", *Renewable Sustain. Energy Rev.*, vol. 150, p. 111509, octubre de 2021. Accessed Oct. 11 2023. [Online]. Aviable: https://doi.org/10.1016/j.rser.2021.111509

[21] C. A. de Lemos Chernicharo y T. Bressani-Ribeiro, Eds., *Anaerobic Reactors for Sewage Treatment: Design, Construction and Operation*. IWA Publ., 2019. Accessed Oct. 11 2023. [Online]. Aviable: https://doi.org/10.2166/9781780409238

[22] J. Pacheco, "Evaluación técnica de la eficiencia de remoción de materia orgánica de agua residual proveniente del Servicio Nacional Textil - SENATEX en un biorreactor UASB a escala laboratorio.", Tesis de grado, Univ. Mayor SAn Andres, La Paz, 2023. [Online]. Aviable: http://repositorio.umsa.bo/xmlui/handle/123456789/31251

[23] k.J. Fernández-Andreade et al. “Evaluation of mass transfer in packed column for competitive adsorption of Tartrazine and brilliant blue FCF: A statistical analysis”, *Results Eng.*, vol.14, p.100449, junio de 2022. Accessed Oct. 19 2023. [Online] Aviable: https://doi.org/10.1016/j.rieng.2022.10044

[23] C. Menéndez y S. Pires, *Tratamientos de agua y Gestión y Tratamiento de residuos*. La Habana: Ed. CUJAE, 2011. [Online]. Aviable: https://www.researchgate.net/profile/Carlos-Menendez-Gutierrez/publication/284188773_Tratamiento_de_Agua_y_Gestion_y_Tratamiento_de_Residuos/links/5655bda308aefe619b1b68d2/Tratamiento-de-Agua-y-Gestion-y-Tratamiento-de-Residuos.pdf

[24] M. Fernández, “Diseño de un reactor anaerobio UASB para el aprovechamiento energético de residuos lácteos a escala piloto”, Tesis de grado, Univ. Central "Marta Abreu" Villas, Santa Clara, 2020. [Online]. Aviable: https://dspace.uclv.edu.cu/handle/123456789/19

[25] N. Deliiski, N. Tumbarkova y G. Zlateski, “Computation by visual fortran of polinoms, obtained by means of software package Table Curve 2d”, *Int. J. - Wood, Des. & Technol.*, Vol.7, No.1, pp. 15–22, 2018. [Online]. Aviable: http://94.149.148.70/en/wood_journal/archive/vol_7_no1/vol_7_no1_fulltext_3

[26] A. Forero, “Diseño y construcción de un prototipo de biorreactor para determinación de coeficientes cinéticos de tratamiento de agua residual para el laboratorio de tratamiento de aguas de la Universidad Santo Tomás - Sede Bogotá”, Tesis de grado, UNIV. ST. TOMAS, Bogotá, 2021. Accessed el 10 de octubre de 2023. [Online]. Aviable: http://hdl.handle.net/11634/37718

[27] Y. Pererva, C. D. Miller y R. C. Sims, “Approaches in Design of Laboratory-Scale UASB Reactors”, *Processes*, vol. 8, n.º 6, p. 734, junio de 2020. Accessed Oct. 19 2023. [Online]. Aviable: https://doi.org/10.3390/pr8060734

[28] I. Dunn, E. Heinzle, J. Prenosil y I. J, *Biological Reaction Engineering*. Wiley, 2003.

[29] T. T. U. Dinh, S. Soda, T. A. H. Nguyen, J. Nakajima y T. H. Cao, “Nutrient removal by duckweed from anaerobically treated swine wastewater in lab-scale stabilization ponds in Vietnam”, *Sci. Total Environ.*, vol. 722, p. 137854, junio de 2020. Accessed el 13 de octubre de 2023. [Online]. Aviable: https://doi.org/10.1016/j.scitotenv.2020.137854

[30] X. Dai *et al.*, “Biomethane production by typical straw anaerobic digestion: Deep insights of material compositions and surface properties”, *Bioresource Technol.*, vol. 313, p. 123643, octubre de 2020. Accessed el 13 de octubre de 2023. [Online]. Aviable: https://doi.org/10.1016/j.biortech.2020.123643

[31] MathWorks. “MATLAB Documentation”. MathWorks - Makers of MATLAB and Simulink - MATLAB & Simulink. Accessed el 13 de octubre de 2023. [Online]. Aviable: https://www.mathworks.com/help/matlab/

[32] I. Simeonov, “Laboratory experiments and mathematical modelling of anaerobic digestion of organic wastes in a cascade of two bioreactors”, *Екологично инженерство и опазв. на околната среда*, No.2, pp. 75–82, 2019. Accessed el 4 de octubre de 2023. [Online]. Aviable: http://ecoleng.org/archive/2019/2/75-82

[33] Y. Tao *et al.*, “Biogas productivity of anaerobic digestion process is governed by a core bacterial microbiota”, *Chem. Eng. J.*, vol. 380, p. 122425, enero de 2020. Accessed el 13 de octubre de 2023. [Online]. Aviable: https://doi.org/10.1016/j.cej.2019.122425

Journal of Engineering and Technology for Industrial Applications

ITEGAM-JETIA

Manaus, v.9 n.44, p. 18-24. Nov/Dec, 2023

DOI: https://doi.org/10.5935/jetia.v9i44.870

ISSN ONLINE: 2447-0228

RESEARCH ARTICLE OPEN ACCESS

THE USE OF PERMEABLE ASPHALT FOR THE BENEFIT OF DRAINAGE SYSTEMS IN URBAN AREAS - A LITERATURE REVIEW

Knopy Lima Lustosa*[1], Francisco Luís da Silva dos Santos Júnior[2] and Heyder de Souza Castro Oliveira[3]

[1, 2, 3] Christus Faculdade do Piauí – CHRISFAPI. Piripiri, Piauí, Brazil.

[1] http://orcid.org/0009-0000-1590-9143, [2] http://orcid.org/0009-0004-8772-0218, [3] http://orcid.org/0000-0003-4175-0732

Email: *knopylustosa1@gmail.com, franciscoluisjr@gmail.com, heyder_castro17@hotmail.com

ARTICLE INFO

Article History
Received: July 05th, 2023
Revised: November 20th, 2023
Accepted: December 15th, 2023
Published: December 30th, 2023

Keywords:
Permeable asphalt,
Sustainability,
Urban drainage.

ABSTRACT

Due to the high population growth rate in urban areas, the evolution of infrastructure is necessary in order to keep up with the demand. However, this growth brings a series of challenges, such as the increase in impermeable surfaces, resulting in high runoff peaks and an increase in flood occurrences. This situation has negative environmental, social, and economic consequences, requiring the adoption of measures to address them. In light of this, a literature review was conducted with the aim of analyzing the benefits of using permeable asphalt in aiding conventional drainage systems. The methodology adopted for this study was a bibliographic review, in which literature addressing urban drainage, drainage systems, and permeable asphalt were analyzed. After conducting the study, it can be concluded that the use of permeable asphalt is highly effective in mitigating the problems caused by floods. However, factors such as application and purpose in a specific location need to be evaluated, in addition to conducting a thorough study to assess economic feasibility.

I. INTRODUCTION

Due to uncontrolled population growth and the human need to develop infrastructure, the expansion of urban areas into rural regions has become an inevitable option. The increasing occupation and paving of land, coupled with the absence of adequate ecosystem planning and limited sanitary and stormwater sewage systems, have resulted in the increase of impermeable areas such as streets, roads, sidewalks, parking lots, and avenues [1].

According to Pezente (2018) [2], urbanization leads to a significant increase in impermeable areas, which causes rainwater to accumulate on the impermeable surface. This accumulation intensifies surface runoff and increases the velocity of flow in pipes and channels, restricting infiltration capacity in the soil and causing alterations in the hydrological cycle.

During flooding events, cities face difficulties in allowing natural drainage of rainwater and rely on public drainage systems to ensure rapid water runoff. When drainage systems fail, streets and avenues become vulnerable, resulting in the occurrence of floods and causing various problems such as the spread of diseases, financial losses, negative impacts on health, and loss of human, animal, and plant lives [3].

As a consequence of the vulnerability presented by these drainage systems, it has been essential to develop new methods and effective techniques to mitigate the impacts of flooding in urban areas. Therefore, the adoption of measures to reduce the volume of surface runoff is indispensable [4].

Permeable pavements are examples of systems capable of restoring the natural hydrological cycle in urban centers, allowing for increased evapotranspiration and infiltration capacity [5]. Their main function is to infiltrate rainwater through layers that make up the system. The high porosity in the surface layer gives it specific prominence [6].

Based on the aforementioned, a study was conducted with the aim of analyzing the benefits of using permeable asphalt as an aid to drainage systems, as well as examining the characteristics of permeable asphalt compared to conventional asphalt, evaluating its technical and economic viability.

II. METHODOLOGY

For the development of this article, a literature search was conducted, presenting aspects related to drainage systems, characteristics of permeable asphalt, and a comparison with conventional asphalt, as well os its technical and economic viability. The research relied on references from books, scientific articles, journals, and websites, including the CAPES Periodicals Portals and Google Scholar, using keywords such as permeable asphalt, sustainability, and urban drainage.

As inclusion criteria, it was defined that the full articles should be in Portuguese, English, or Spanish, within the time frame from 2014 to 2023, and address permeable asphalt and urban drainage. As exclusion criteria, articles without an objective methodology and studies without open access were excluded.

Through the literature search conducted on the CAPES and Google Scholar databases, a total of 1,370 articles were found according to the search terms and year, as shown in the Flowchart in Figure 1. After this step, titles, abstracts, and descriptors were read and analyzed based on the inclusion and exclusion criteria, resulting in the selection of 48 articles. During the final selection of articles to be used, 18 were chosen according to the central theme of the present article.

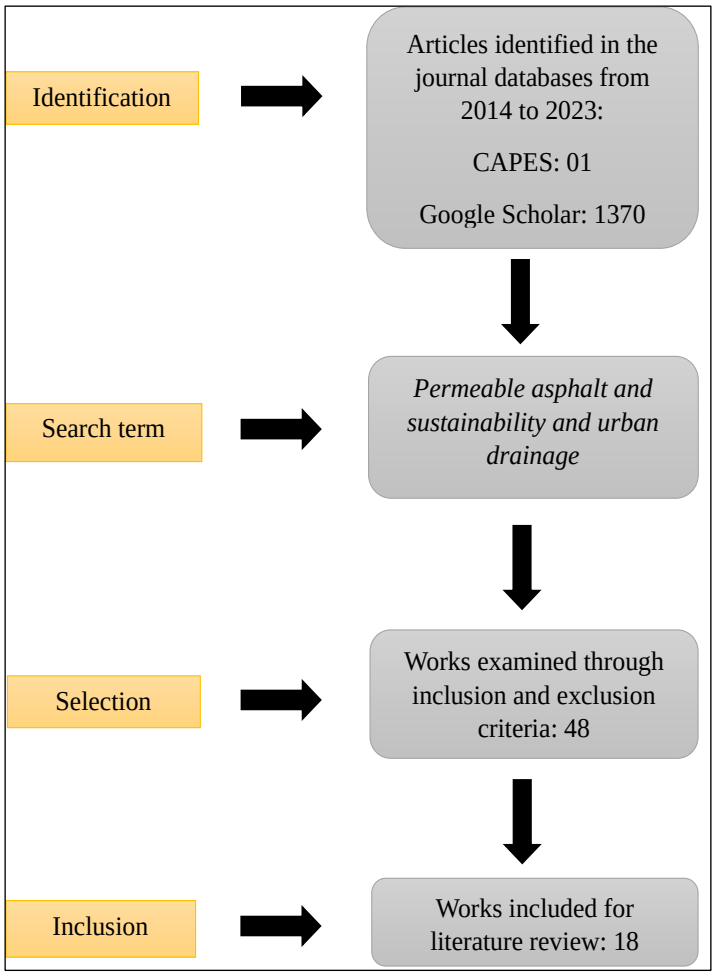


Figure 1: Flowchart for Article Selection in the Literature Review.
Source: Authors, (2023).

The present study is classified as a qualitative theoretical research in the exploratory category. The qualitative research was conducted through a literature review, with the selection of specific bibliography that covers the following themes: urban drainage, sustainability, and permeable pavements.

III. THEORETICAL REFERENCE

III.1 URBAN DRAINAGE

Urban drainage system is understood as a process that aims to prevent floods and inundations, especially in low-lying areas of communities susceptible to such conditions [7]. In recent years, urban development has grown haphazardly, resulting in degrading consequences in many regions due to increased occupied spaces. As a result, during rainy seasons, there is a constant increase in floods in cities, causing a reduction in quality of life due to the risks of epidemics and diseases [8].

Sustainable socioeconomic and human growth is of paramount importance for the development of cities, requiring solutions to problems related to the management and control of stormwater. Through urban planning as a legal norm, the objective is to establish the development of collective urban obligations and ensure the convenience of the population. However, it is concerning to note that most cities still do not give due importance to planning or the drainage master plan, lacking a specific project for this category [9].

The Drainage and Urban Development Master Plan needs to involve actions for planning and distribution of water, incorporating structural measures that affect the flow properties, altering the course and management of water flow, leading to a change in the natural drainage system [9]. Therefore, it is a fundamental and essential instrument of principles for urban evolution and growth, contributing to the recognition, safety, and balanced control of natural resources [7].

Ineffective and obsolete urban systems occur mainly in small municipalities, and this is justified by the difficulty in local management and planning. These municipalities develop in a disorderly manner until they approach the legally defined number of residents, and only after that, the plan is chosen [7]. In the face of the current scenario of population growth, devices and systems have been created to mitigate the effects of deficiencies in drainage systems and urban flooding [4].

III.2 DRAINAGE SYSTEMS

The hydrological cycle is a natural process that involves the continuous movement of water between the atmosphere and the Earth's surface, playing a vital role in the functioning of the environment. Water flows freely along the longitudinal extent of the surface until it encounters a water body or infiltrates into underground reservoirs. However, when an area becomes urbanized, water no longer follows its natural path but is instead directed by mechanisms that change its trajectory and redirect it to another location. These mechanisms capable of directing or diverting stormwater in specific areas are expressed as drainage systems [7].

Urban drainage systems are divided into microdrainage and macrodrainage. The microdrainage system consists of devices that channel surface runoff into galleries or open channels. It includes features such as curbstones, gutters, catch basins, connecting pipes, galleries, and manholes [10], as shown in Figures 2 and 3.

- Curbstone: a long strip that separates the sidewalk from the road.
- Gutter: a channel installed between the curbstone and the road, designed to receive and convey water to catch basins or manholes.

- Catch basin: a device that captures surface water runoff from the gutter.
- Connecting pipes: conduits responsible for conveying the captured runoff from catch basins to manholes or galleries.
- Gallery: public conduits that receive runoff water from connecting pipes, directing it towards the city's streams.
- Manhole: a device that provides access to underground networks, allowing for control of changes in the hydraulic system and cleaning of conduits.

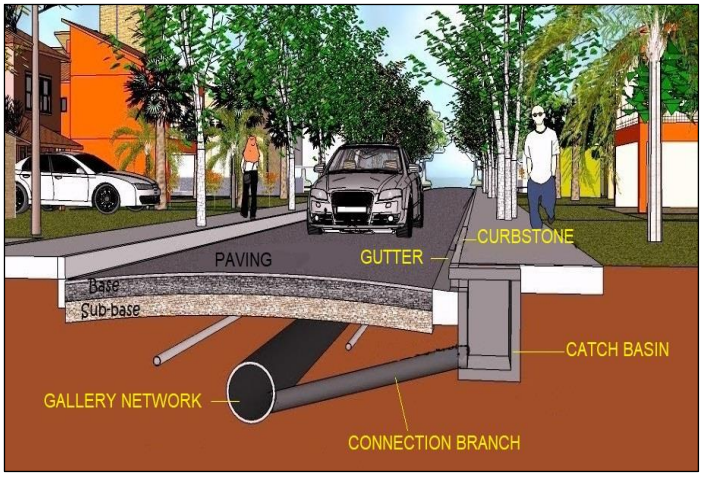


Figure 2: Illustration of various microdrainage mechanisms in a paved road.
Source: Authors, (2023).

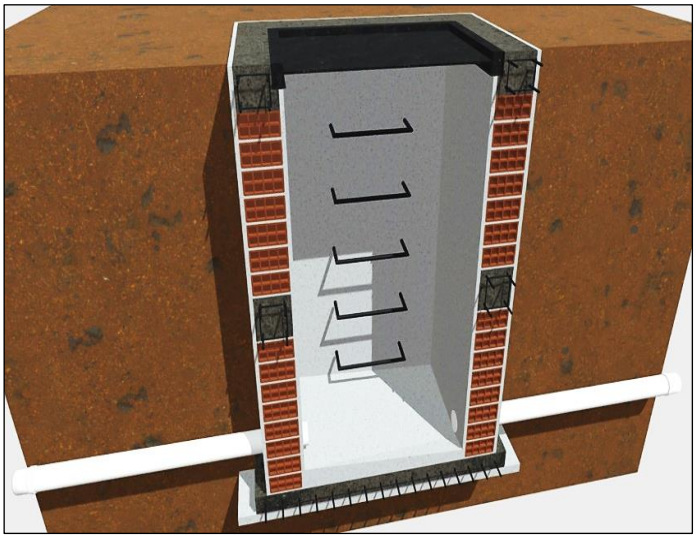


Figure 3: 3D Manhole.
Source: Authors, (2022).

The macrodrainage system is responsible for the final drainage of water resulting from the microdrainage system. It optimizes the flow and minimizes disruptions caused by sedimentation and floods in the main channels, consisting of streams or rivers that cross the city [10].

As shown earlier, drainage systems have specific characteristics that, depending on the situation faced by the city, may or may not solve the problems [10], as depicted in Figure 4.

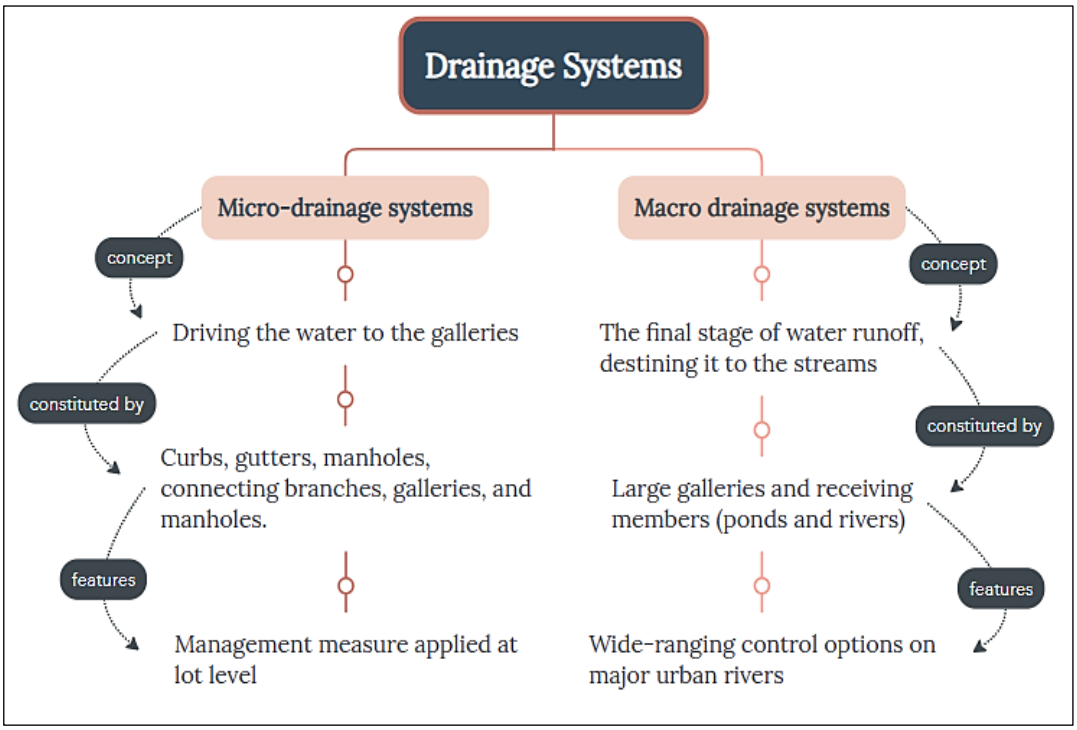


Figure 4: Drainage Systems Organogram.
Source: Authors, (2023).

However, it is evident that drainage systems are becoming obsolete and incapable of efficiently fulfilling their function due to uncontrolled urban growth [9]. Therefore, there is a need to create methods that promote sustainable development of urban drainage, expanding the infrastructure and making the urban environment conducive to a better quality of life [8].

IV. PERMEABLE ASPHALT (PA)

Permeable asphalt is a device designed to allow the passage of fluids, such as rainwater, while also providing resistance to vehicle traffic, pedestrians, and objects. Its main function is to temporarily retain water, using materials with porous

characteristics that promote drainage through infiltration into the subsoil. These infiltration zones receive water from impermeable areas, restoring the potential for replenishing groundwater reserves. [11].

Permeable asphalt is composed of layers of aggregates, differentiated by their particle size distribution, which allows for an increased void volume with water storage capacity, distinguishing it from conventional asphalt [15].

The surface covering of permeable pavement exhibits porosity and excessive permeability, positively influencing the hydrological cycle, particularly in terms of surface runoff. This allows water to infiltrate the surface and move into the reservoir of stones, where it is stored before further infiltration into the soil [3].

According to Santos (2017) [10], permeable pavement is composed of different layers that perform specific functions. The top layer, known as the surface layer, consists of small stones mixed with asphalt. This composition allows for the permeability of rainwater, enabling its infiltration into the soil. The deeper layers are composed of larger stones, creating a void space of approximately 25% of the total volume. This composition ensures that water can infiltrate through the smaller stones and be stored. Thus, rainwater is captured by the drainage system and directed towards the stormwater galleries, as depicted in figure 5.

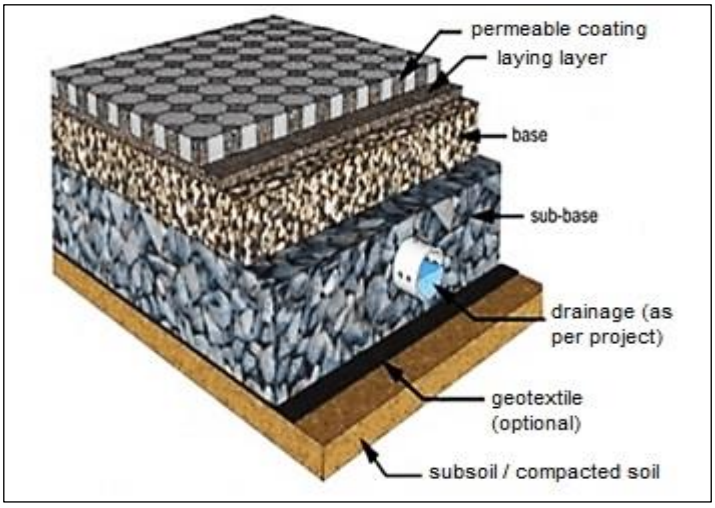


Figure 5: Representation of the main layers of the permeable pavement system.
Source: Adapted from [18].

Porous pavements contain porous asphalt, porous concrete, blocks, and other construction systems that can be used in urban areas. They are made from practically the same materials, even though they have different connotations, as shown in table 1 [15].

Table 1: Components and elements used in permeable sidewalks.

Terminology Applied to Porous Pavements	
Terminology	**Definition**
Base Layer	A layer placed below the surface pavement to increase the thickness of the pavement. It can simply be referred to as Base.
Layer	Space occupied between two types of materials in the pavement structure.
Filter Layer	Any layer between other layers or between the pavement and subgrade that prevents the migration of particles into the voids od the underlying layer.
Geomembrane	Impermeable fabric, usually plastic or High-Density Polyethlene (HDPE), used in waterproofing systems.
Geotextile	Non-woven fabric made of polypropylene filaments that allows the free passage of infiltration water to the drainage medium.
Pavement	Any treatment or covering on the surface that supports any type of traffic.
Overlay	Layer applied over any existing pavement.
Pavement Structure	Combination of material layers placed over the subgrade that provide mechanical support of the pavement.
Reservoir	Any part of the pavement with water storage capacity and conductivity. The reservoir can be overlaid or combined with other pavement layers. Also known as Base Reservoir, Drainage Layer, or Drainage Bed.
Subbase	Layer placed below the Base layer to increase the thickness os the pavement.
Subgrade	Natural or reinforced soil below the pavement structure, responsible for ultimately absorbing the loadings.
Surface Layer	The layer of the pavement that directly receives the traffic load.

Source: Adapted from [15].

Porous pavement presents itself as a new alternative for roads. With a simple application, the materials used are practically the same as conventional asphalts, even though they have different connotations, and as an advantage, it can contribute to drainage issues in large urban centers [15].

Porous pavements have two functions that characterize their structure [15]:

- Mechanical Function: It is possible to determine the load imposed by vehicle traffic through the analysis of the type of structure used.
- Hydraulic Function: Regarding storage, there is a temporary deposition of water through the porosity of the materials, allowing drainage and infiltration into the soil when feasible.

The classification of pavement types that have functions related to urban and stormwater drainage is as follows:

- Pavements with permeable surfaces: They allow rainwater to reach the lower layers of the pavement and cause a rapid decrease in surface runoff.
- Porous pavements for retention: They serve the function of temporarily storing rainwater, without infiltration, and are divided into:
  - Porous storage pavements with direct infiltration, with permeable surfaces.
  - Porous pavements for retention with indirect infiltration, with impermeable surfaces.
- Porous infiltration pavements: They perform two different functions of temporary storage and penetration of rainwater, divided into:
  - Porous infiltration pavements with distributed infiltration, with permeable surfaces.
  - Porous infiltration pavements with localized infiltration, with impermeable surfaces.

In terms of their use, each of these different types of pavements has a specific structure [15].

In densely populated urban areas, the area allocated for road networks and parking lots occupies a considerable space, sometimes reaching up to 30% of the area of a drainage basin [12]. The use of permeable pavement plays a crucial role in addressing the difficulties caused by urban flooding, as it contributes to the reduction of surface runoff. This type of pavement possesses distinct properties, such as high porosity and good drainage capacity, determined by its appropriate gradation [13].

The use of this pavement is recommended for areas in industrial, commercial, and residential sectors, warehouses, yards, lightly trafficked streets, in condominiums and housing complexes, parks, sidewalks, and parking lots [14]. In light of this, it offers considerable advantages for its functionality. However, despite being an innovative technology that promotes environmental preservation, the applicability of permeable pavement is still limited. In Figure 6, we can observe a table with its main advantages and disadvantages (or precautions) [11].

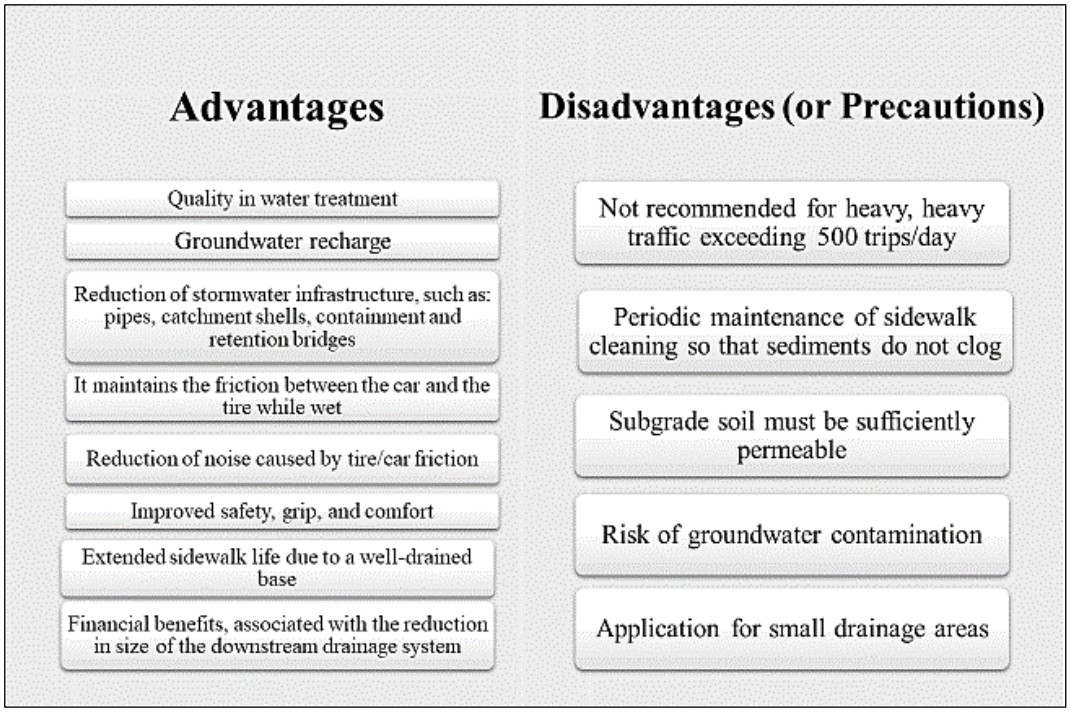


Figure 6: Table of Advantages and Disadvantages (or Precautions).
Source: Authors, (2023).

Permeable pavement stands out as one of the most efficient alternatives to solve these problems due to its ability to adapt to the urban environment, promoting ecological balance and ensuring economic viability. In light of the aforementioned, the implementation of permeable pavement encourages society to embrace activities that ensure the preservation of urban areas, employing effective methods that contribute to the management of surface drainage and minimize the damages caused by improper land occupation, which leads to impermeability [12].

V. RESULTS AND DISCUSSIONS

V.1 TECHNICAL FEASIBILITY

Perrone and Souza (2019) indicate that the composition of asphalt varies according to its purpose, and as the strength increases, the permeability capacity decreases. Permeable asphalt has void ratios of up to 25%, while conventional asphalt has a void ratio of 4%. Conventional asphalt is primarily used for traffic pavement, whereas permeable asphalt has some limitations in terms of performance, such as slope. If a permeable asphalt road has a steep slope, the rate of water infiltration will be reduced [13].

To efficiently drain surface water, permeable asphalt is designed with a specific particle size distribution that results in a high void ratio, which is the main difference between permeable and conventional asphalt [13]. In conventional asphalt, the surface layers are made impermeable to provide greater mechanical strength [7].

The formation of permeable pavement is similar in certain aspects to conventional pavements, such as the top layer being constructed in the same way, but with a difference in retaining the sand fraction combined with aggregates that compose the pavement, resulting in an open grading. As a result, this grading provides an asphalt mixture with 18% to 25% voids, allowing for rapid water percolation [16].

The urban functions of permeable pavement are similar to those of conventional pavement, with the difference lying in its ability to reduce surface runoff from stormwater. Technical standards assist professionals in developing calculations for the hydraulic aspects, traffic, and pavement layers concerning permeable asphalt [17].

Therefore, Mello and Rigo (2023) [18] point out the Brazilian standard ABNT NBR 16.416/2015, which requires permeable asphalt to simultaneously meet mechanical stresses and rolling conditions while facilitating water percolation or temporary accumulation within its structure.

Permeable pavements can be classified into different types, such as porous asphalt, porous or pervious concrete, and permeable pavers, as shown in Table 2.

Table 2: General properties of permeable pavements.

	Porous Asphalt	**Porous or cast concrete**	**Parallelepipeds**
Slope	2%	2%	4%
Constituition	Fine sand fraction (open gradation) of the sidewalk aggregate mix	Granular material, such as sand, and filled with undergrowtch, such as grass	Granite is an igneous rock, which presents in its composition quartz, feldspar, mica, amphibole, pyroxene, and olivine
Resistance	Medium	Average to good	Medium
Emptiness	18% to 25% voids, fast water percolation	15% to 25% average water percolation	15% to 25% average water percolation
Capability	Good	Good	Medium

Source: Adapted from [10].

It can be observed that porous asphalt and porous concrete demonstrate a good absorption capacity, which is essential for efficient drainage. In this regard, porous asphalt has an even greater advantage as it provides faster water percolation, contributing to the reduction of surface accumulation and minimizing problems related to floods and inundations. This characteristic makes porous asphalt a highly recommended option in urban areas subject to high precipitation volumes. [10]. In Table 3, the accumulated values of runoff and water infiltration are presented, highlighting the efficiency of permeable pavements.

Table 3: Cumulative values of runoff and water infiltration in different sections.

Treatment	**Cumulative precipitation (mm)**	**Surface runoff (mm)**	**Infiltration (mm)**
Asphalt	236,62	168,00	68,62
Parallelepiped	236,62	51,64	185,28
Gramado	236,62	5,00	231,62
Permeable sidewalk: porous asphalt and porous concrete	236,62	0,00	236,62

Source: Adapted from [10].

According to Santos (2017) [10], the table demonstrates the effectiveness of permeable pavements compared to the most commonly used pavement type in Brazilian cities. Conventional asphalt shows a limited capacity for rainwater infiltration, with results below 29%, resulting in approximately 71% of surface runoff.

V.2 ECONOMIC VIABILITY

From an economic standpoint, the use of permeable pavement proves to be a highly viable solution. Although there are additional maintenance and construction costs compared to conventional pavements, these costs are often offset by the reduction in expenses related to drainage systems, as peak flows are reduced. This results in long-term savings. [7].

Based on the information presented in Table 4, obtained from the study conducted by [15], it is possible to establish a comparison between some aspects of permeable pavement in relation to conventional concrete and asphalt.

Table 4: Comparison between types of pavement.

Material/Criterial	**Permeable Asphalt**	**Concrete**	**Convencional Asphalt**
Maintenance Frequency	Veried depending on usage (6 monthrs to 2 years	6 months to 2 years	Depends on location
Implementation cost	Medium	Medium	Medium
Maintenance cost	Medium to high	Medium to high	Low
Type of use	All, as long as reinforced	All, as long as reinforced	Structure is used, All
Absorption capacity	Good	Good	None
Acoustics	Good	Good	Average

Source: Adapted from [15].

According to Mello and Rigo (2023) [18], permeable pavement is a widely studied and standardized alternative regulated by ABNT NBR 16.416/2015. This standard establishes the minimum conditions required for the design, specifications, and execution of permeable pavements, and it is regulated by municipal laws. However, it is important to note that there are still limitations regarding the available information for cost estimation, requiring a more comprehensive analysis for its application.

VI. CONCLUSION

The use of permeable asphalt is a highly effective measure to combat floods and urban inundations, providing a range of environmental benefits. Among these benefits, the restoration of groundwater levels, increased moisture in urban green areas, and improved quality of infiltrated water are noteworthy, as permeable pavement is capable of filtering impurities.

Although economic feasibility is favorable, it is essential to conduct a comprehensive field study to accurately assess construction and maintenance costs related to implementation and labor, especially in public infrastructure projects. This need became evident during the literature review, emphasizing the importance of a more in-depth analysis for informed decision-making.

From a technical standpoint, permeable asphalt demonstrates highly satisfactory performance compared to

conventional asphalt. However, it is important to highlight that there are significant differences in terms of mechanical strength, which requires careful analysis when considering its application in areas with heavy traffic. In-depth studies are necessary to fully understand the load-bearing capacity of permeable asphalt under such conditions, ensuring its durability and safety in high-traffic environments.

Based on the authors cited in this research, it was possible to highlight that the use of this type of pavement is an efficient and relevant solution to mitigate the problems faced during periods of rain in urban areas, bringing significant improvements to drainage systems. Therefore, it can be concluded that the objectives of this research were achieved, emphasizing the importance of conducting additional studies focused on the economic viability of this solution.

VII. AUTHORS' CONTRIBUTION

Conceptualization: Knopy Lima Lustosa.
Methodology: Knopy Lima Lustosa and Francisco Luís da Silva dos Santos Júnior.
Investigation: Knopy Lima Lustosa.
Discussion of results: Knopy Lima Lustosa and Francisco Luís da Silva dos Santos Júnior.
Writing –Original Draft: Knopy Lima Lustosa and Francisco Luís da Silva dos Santos Júnior.
Writing –Review and Editing: Knopy Lima Lustosa.
Resources: Knopy Lima Lustosa and Francisco Luís da Silva dos Santos Júnior.
Supervision: Knopy Lima Lustosa and Heyder de Souza Castro Oliveira.
Approval of the final text: Knopy Lima Lustosa, Francisco Luís da Silva dos Santos Júnior, and Heyder de Souza Castro Oliveira.

VIII. REFERENCES

[1] C. de A. Santos, "Impacto da Utilização de Pavimentação Permeável em Áreas Urbanas na Recuperação de Bacias Hidrográficas", tede.unioeste.br, abr. 2016, Acesso em: 25 abr. 2023. [Online]. Disponível: https://tede.unioeste.br/handle/tede/805.

[2] M. F. M. Pezente. "Relação entre urbanização e rios: Um estudo da cidade de Francisco Beltrão (PR)". Repositório Institucional da UFSC. https://repositorio.ufsc.br/handle/123456789/198544 (consult. 2023-08-21).

[3] E. M. A. Santos, C. R. Silveira, M. D. M. F. Morais e J. C. L. Bueno, "ANÁLISE DA VIABILIDADE ECONÔMICA DE IMPLANTAÇÃO DE PAVIMENTO PERMEÁVEL COMO INSTRUMENTO DE DRENAGEM URBANA NAS VIAS MAIS ALAGADAS DO MUNICÍPIO DE NOVA XAVANTINA –MT", Revista Interação Interdisciplinar (ISSN: 2526-9550), vol. 3, n. 2, 2019, Acesso em: 25 abr. 2023. [Online]. Disponível: https://publicacoes.unifimes.edu.br/index.php/interacao/article/view/799.

[4] N. M. . Rodrigues, C. E. F. . Rodrigues, e C. R. . Rodrigues, "A falta de drenagem urbana nas cidades brasileiras", RSD, vol. 11, nº 6, p. e54911629652, maio 2022.

[5] A. Niehuns Lucas, "Avaliação ambiental do aproveitamento de água pluvial infiltrada em um sistema de pavimento permeável em comparação com um sistema de drenagem convencional por meio da avaliação do ciclo de vida," 2020, Acesso em: 25 abr. 2023. [Online]. Disponível: https://repositorio.ufsc.br/handle/123456789/216124.

[6] L. K. Berto, G. Godoi, L. P. Amaro, M. Corso, J. R. Ribeiro e L. C. S. H. Rezende, "ANÁLISE DA RELAÇÃO ENTRE A PERMEABILIDADE E AS CARACTERÍSTICAS MECÂNICAS DO REVESTIMENTO ASFÁLTICO PERMEÁVEL", REVISTA DA UNIVERSIDADE VALE DO RIO VERDE, vol. 16, n.º 2, 2018, doi: https://doi.org/10.5892/ruvrd.v16i2.4964.

[7] P. A. C. Martins, "Benefícios da implementação de pavimentos permeáveis em sistemas de drenagem sustentável em zonas urbanas", repositorio.animaeducacao.com.br, dez. 2022, Acesso em: 11 de maio de 2023. [Online]. Disponível: https://repositorio.animaeducacao.com.br/handle/ANIMA/29629.

[8] A. De, U. Drenagem, U. Sustentável, G. Meller, F. Dreshch e G. Daronco, "Modalidade do trabalho: Relatório técnico-científico Evento: XXII Seminário de Iniciação Científica." Disponível: https://publicacoeseventos.unijui.edu.br/index.php/salaoconhecimento/article/view/3432/2833.

[9] C. de Sousa dos Santos, A. C. Rangel, e J. R. Gonçalves, ANÁLISE DA DRENAGEM URBANA COM ÊNFASE NA REDUÇÃO DE RISCOS DE ENCHENTES, Revista Augustus, vol. 24, nº 48, p. 146-158, out. 2019.

[10] S. L. Santos, "Pavimentos permeáveis no controle de cheias urbanas", Ifg.edu.br, 2020, doi: http://repositorio.ifg.edu.br:8080/handle/prefix/1055.

[11] M. A. de O. Gouveia, "ASFALTO DRENANTE: PROPORÇÕES GRANULOMÉTRICAS E APLICABILIDADE," repositorio.ifgoiano.edu.br, Jun. 2019, Accessed: Jun. 02, 2023. [Online]. Available: https://repositorio.ifgoiano.edu.br/handle/prefix/559.

[12] L. M. de Souza, "Utilização de resíduos da construção e demolição (RCD) em formulações de revestimentos para pavimentação urbana permeável," repositorio.animaeducacao.com.br, 2022, Available: https://repositorio.animaeducacao.com.br/handle/ANIMA/25762.

[13] W. Perrone e W. de Souza, "ESTUDO DE VIABILIDADE TÉCNICA DA IMPLANTAÇÃO DE SISTEMA DE DRENAGEM COM UTILIZAÇÃO DE ASFALTO PERMEÁVEL, COMO ALTERNATIVA DE MITIGAÇÃO DE INUNDAÇÕES, EM ÁREAS URBANAS DE MANAU"S, JETIA, vol. 5, nº 19, p. 36-40, set. 2019.

[14] E. ABCP, "Pavimento Permeável," PORTAL ABCP, Jan. 06, 2016. https://abcp.org.br/pavimento-permeavel/ (accessed Jun. 02, 2023).

[15] R. S. A. de Abreu and T. V. Miranda, "O uso do pavimento permeável como medida auxiliar na drenagem das cidades," Revista Científica Multidisciplinar Núcleo do Conhecimento, pp. 52–74, Apr. 2020, doi: https://doi.org/10.32749/nucleodoconhecimento.com.br/engenharia-civil/pavimento-permeavel.

[16] S. Wesley, "Estudo de revestimento asfáltico permeável," 146.252, 2020, doi: http://104.207.146.252:8080/xmlui/handle/123456789/474.

[17] D. Lembi, Francisco, Santos, P. Roberta Dos, Silva, and D. Domingos Da, "ASFALTO PERMEÁVEL PERMEABLE ASPHALT," no. 10, 2018, Accessed: Jun. 02, 2023. [Online]. Available: http://www.faip.revista.inf.br/imagens_arquivos/arquivos_destaque/OeelpMfTbV5y5HL_2019-10-23-15-10-21.pdf.

[18] F. B. G. Mello e D. Rigo, "Comparativo de custos de implantação de pavimento convencional e pavimento permeável," Revista Científica Multidisciplinar Núcleo do Conhecimento, vol. 04, no. 04, pp. 05-25, Apr. 2023, doi: 10.32749/nucleodoconhecimento.com.br/engenharia-civil/pavimento-convencional.

Journal of Engineering and Technology for Industrial Applications

ISSN ONLINE: 2447-0228

ITEGAM-JETIA

Manaus, v.9 n.44, p. 25-34. Nov/Dec, 2023

DOI: https://doi.org/10.5935/jetia.v9i44.903

RESEARCH ARTICLE OPEN ACCESS

SINGLE SERVER-SIDE AND MULTIPLE VIRTUAL SERVER-SIDE ARCHITECTURES: PERFORMANCE ANALYSIS ON PROXMOX VE FOR E-LEARNING SYSTEMS

Yuri Ariyanto*[1]

[1] Department of Information Technology, Informatics Engineering, State Polytechnic of Malang, Malang, Indonesia.

[1] http://orcid.org/0000-0001-8678-5184

Email: *yuri@polinema.ac.id

ARTICLE INFO

Article History

Received: September 09th, 2023

Revised: November 06th, 2023

Accepted: November 13th, 2023

Published: December 30th, 2023

Keywords:

Performance Test,
Virtualization,
Reverse Proxy,
Proxmox VE,
E-Learning.

ABSTRACT

At this time, almost all educational institutions use the e-learning system to support learning. The factor that plays the most role in the comfortable use of a system is the performance aspect. This type of single-server architecture is very commonly applied in building a system, but this system is actually less efficient because it does not pay attention to the level of availability. In this study, a server architecture was built in the form of multiple virtual servers utilizing virtualization on Proxmox by applying reverse proxy techniques and storage clustering to increase system availability in building an e-learning Moodle system. The design of multiple virtual server architectures uses prepare, plan, design, implementation, test and optimization methodologies. The results of the research on the testbed and test plan show that the multiple virtual server architecture has superior availability compared to the single server architecture. Based on the User Behavior Modeling Performance (UBMP) test results, the multiple virtual server architecture is also superior, with a maximum value of 100 concurrent users on the multiple virtual server-side architecture, where the availability level is 80.25%, while on the single server, it is lower with a value of 80 users and an availability level of 78.4%.

I. INTRODUCTION

An educational institution can have more than one e-learning system, which in practice generally uses a single server architecture type [1]. A single server architecture is indeed not a problem if it is used for only one system, but if several systems are active simultaneously on it it will be risky, especially when an error occurs on the server then all services will stop meaning a low level of system availability [2]. Another factor that needs to be considered is the aspect of performance and the efficient use of resources, both software and hardware so that they can support the performance and level of system availability [3].

To overcome the problems that exist in the single server architecture, multiple virtual server architecture types are used combined with the application of reverse proxy techniques for efficiency in terms of application software on the Proxmox server [4][5]. The reverse proxy allows the use of a domain name and SSL certificate for multiple applications or e-learning systems at once [6]. Reverse proxy also has load balance and failover features which can increase server availability [7]. Virtualization is the basis for creating cloud computing with the type of Infrastructure as a Service (IAAS) [8]. Server virtualization can also be implemented for cost efficiency in terms of hardware. Virtualization can optimize the use of hardware and avoid wasting electricity so that it is cost-effective [8][9]. Proxmox Virtual Environment (PVE) is a high-availability hypervisor that can be used to create and manage virtual machines [10]. PVE can also be used as a virtual server infrastructure in making practical web-based e-learning combined with noVNC technology [11]. In addition to virtualization, storage clustering techniques can also be utilized to increase hardware scalability and availability, especially storage media by placing several storage media in a redundant and distributed manner [12][13].

The use of a single server architecture has various limitations, as previously described [14]. The multiple virtual

server architecture is a server architecture designed by breaking a physical computer into several virtual computers so that it can make efficient use of hardware and increase system availability by optimizing interactions between existing virtual servers. The application of a reverse proxy has various functions, such as cost effectiveness and increasing system availability by utilizing load balancing [15]. Likewise with storage clustering, which is able to increase availability in terms of hardware [16]. In building an e-learning system, the use of Moodle is very effective from a development standpoint and easy to use from a production standpoint [17]. Moodle in software already has a guaranteed performance benchmark based on various test results that have been carried out by many people, so there is little possibility of a software bottleneck when building an e-learning system using Moodle [18].

Related to some of these things, this research applies Moodle as an e-learning application that is deployed in a multiple virtual server architecture on Proxmox with the implementation of storage clustering using GlusterFS. The use of a reverse proxy with HAproxy is expected to support aspects of the effectiveness and efficiency of resource use and system availability on the server [19]. Various advantages of the application made in building e-learning systems in research need to be validated in terms of performance in terms of server architecture using a performance analysis method because the performance aspect is very vital in a system. To perform performance analysis, the User Behavior Modeling Performance (UBMP) method is used [20]. UBMP is a performance test model that is effective, comprehensive, and broad so that it can be applied to various server architectures, especially in cloud environments [21]. In testing this method, we comprehensively reviewed the performance of the server architecture models tested.

The purpose of this study is to use User Behavior Modeling Performance (UBMP) with the aim of obtaining effective, comprehensive, and accurate performance assessment results for the architecture being tested [22]. Then a single server-side architecture was also built as a comparison to multiple virtual architectures to analyze its performance and determine the level of reliability of each server architecture. The application of the test environment was carried out by the Proxmox server for server implementation on each architecture using the Debian 8 operating system.

II. THEORETICAL REFERENCE

II.1 MOODLE

Moodle is an e-learning platform designed to provide educators, students, and administrators with one integrated system [23]. E-Learning is the principle of direct learning, and in its application, it promotes independent learning, namely web-based distance learning that can be accessed via the internet network [24]. Moodle provides digital classrooms to access material or anything related to learning that is freely accessible to anyone, anytime, anywhere [25]. The advantage of using Moodle is that it is open source, so someone with programming skills can adjust and develop existing features according to their needs and desires [26].

II.2 REVERSE PROXY

The reverse proxy method is a technique that places a proxy server as a middle layer between the client (the frontend layer) and the server (the backend layer). The use of reverse proxies is generally used as load balancing to share server load and can also run caching features to avoid sending the same content repeatedly so as to reduce web server load [27].

Load balancing on the reverse proxy can minimize downtime so that the system has high availability. Haproxy is software that can be used for reverse proxy and load balancing with reliable performance [28]. In addition, its application can also be used in various cases. Among them is to save on the allocation of domain names with the domain forwarding technique or the SSL termination technique by only placing encrypted communications at the frontend layer so that you can save on the use of SSL certificates.

II.3 VIRTUALIZATION

Virtualization is a computer device where the amount of hardware resources can be created, managed, and allocated as needed through software, and various operating systems can be installed in it [29]. The resources used in virtualization come from the resources owned by the physical computer where the virtual computer is created (the host). Resource allocation can be done because of the hypervisor technology. The hypervisor plays the role of managing, running, and monitoring virtual machines [30].

Virtualization is the basis for cloud computing providers Infrastructure as a Service (IAAS) services [31]. Several cloud service providers, such as Amazon, also use virtualized machine technology in the cloud services they offer. Generally, the purpose of virtualization is to optimize hardware use and avoid wasting electricity. One of the hypervisors with high availability capabilities is Proxmox, which can manage virtual machines with KVM and containers with LCX [32][33]. The proxmox architecture can be seen in Figure 1.

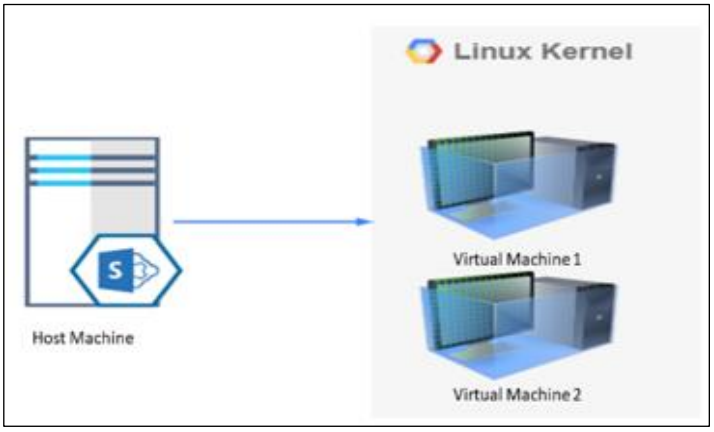


Figure 1: Hypervisor Proxmox Architecture.
Source: Author, (2023).

II.4 TOOL FOR TESTING

There are currently a number of open-source tools that can be used for stress testing web servers or web services. In this article, we focus on tools suitable for generating HTTP and HTTPS loads (GET, POST, and PUT) and FTP loads (PASV and RETR file transfers). Only tools with distribution open licenses (GNU, Apache License, etc.) and executables on the Linux kernel operating system were selected for performance analysis using Apache JMeter [34]. Apache JMeter is open-source software used to perform load testing, performance testing, and functional testing on web applications and other web services [35].

II.5 USER BEHAVIOR MODELING PERFORMANCE (UBMP)

The scope of performance testing is very broad, and the differences in architecture and resources used in it also affect the aspects tested [36]. UBMP testing will produce a performance test model that is effective, comprehensive, and broad so that it can be applied to various server architectures, especially in cloud environments. The optimum value and maximum concurrent users are important indicators to evaluate system performance. In traditional performance testing, there are problems with high costs and limited resources, so the maximum concurrent users cannot be achieved, and the result is that the maximum access load on the system cannot be estimated.

UBMP overcomes these problems using the inflection point performance index, which is an analysis of the performance index based on three performance indicators, namely CPU usage, throughput, and availability. UBMP divides system performance into three parts based on the optimum value and maximum concurrent users, namely light load, smooth load, and heavy load. The larger the user, the greater the increase in CPU and throughput at a certain point and a decrease in the level of availability. The optimum value for concurrent users is obtained when the throughput is at its maximum. The maximum concurrent user value is obtained when the system availability level drops to 70%.

The light load condition occurs when the number of users is below the user's optimum value, the level of availability is high, and the throughput and CPU start to gradually increase. Smooth load conditions are in the range of optimum values and maximum concurrent users. The heavy load condition occurs when the number of concurrent users is above the maximum concurrent user value.

Testing with UBMP uses several user behavior parameters to simulate testing under real-world conditions. The parameters used are thinking time, ramp-up period, and functional test plan. The UBMP test flow to obtain optimum values and maximum concurrent users to determine light, smooth, and heavy load conditions on the system can be seen in Figure 2.

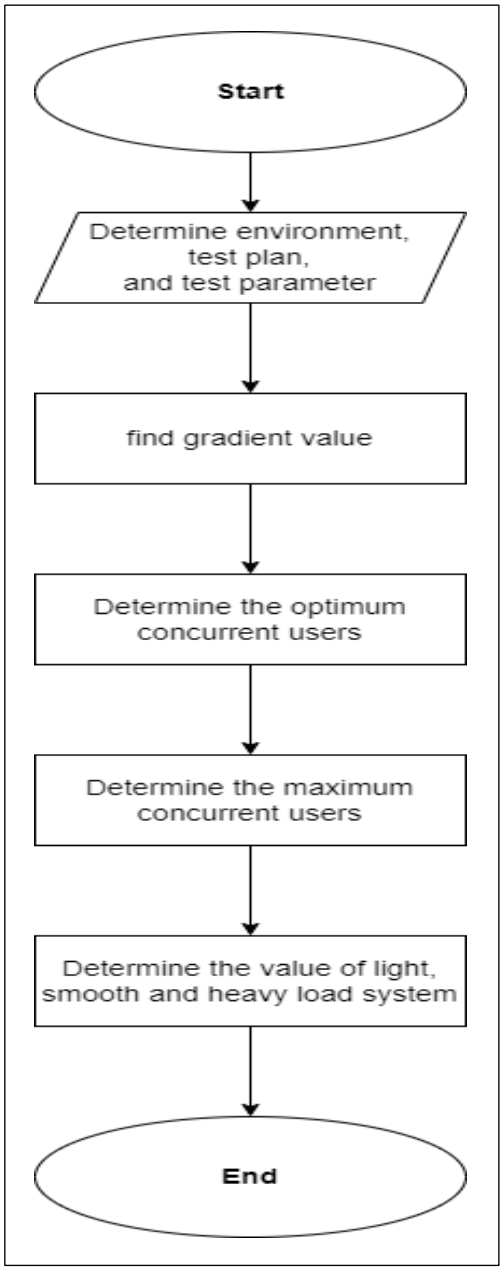


Figure 2: UBMP flowchart.
Source: Author, (2023).

II.5 STORAGE CLUSTERING

Storage clustering is a method of grouping several storage media into a logic storage so that the stored data is distributed among the storage media that are joined in a group [37]. This method is widely applied for the scalability and availability of data storage. If a storage medium is damaged, the data stored is still safe because the data is replicated on other storage media in the cluster. One of the Replication Cluster High-Availability Storage technologies is GlusterFS [38]. The application of storage clustering with glusterFS in this study is used to store user data in Moodle applications on two replicated web servers. The storage clustering scheme used can be seen in Figure 3.

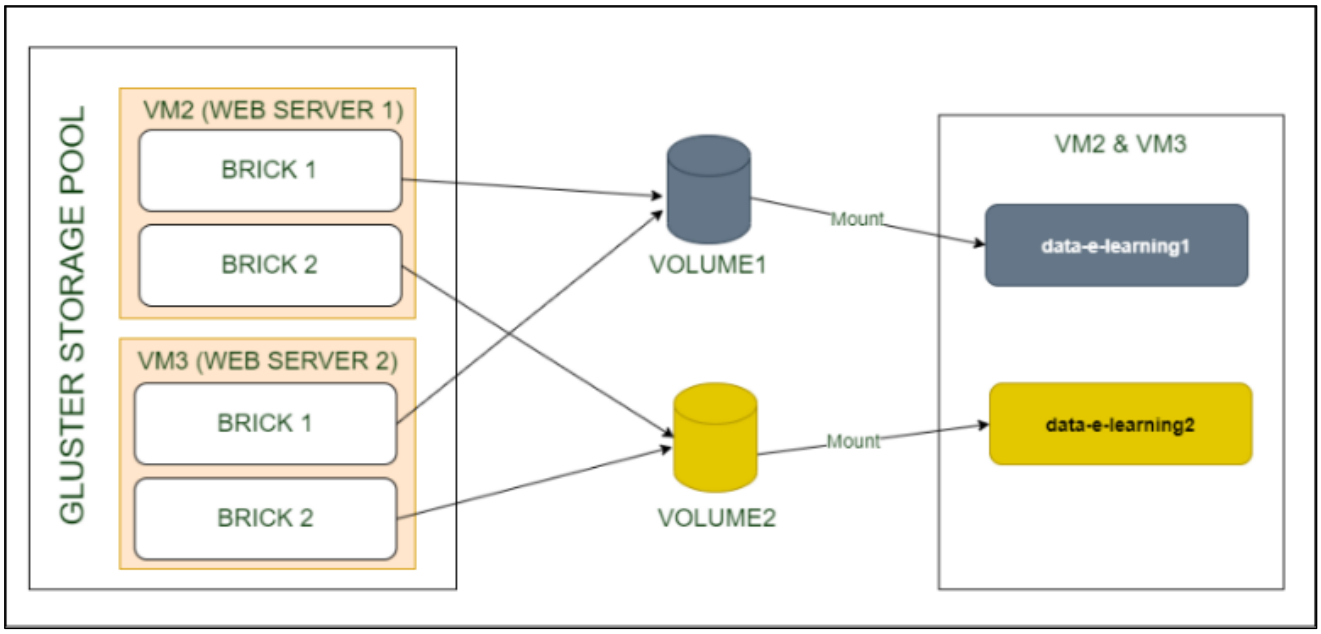


Figure 3: Storage Clustering Architecture.
Source: Author, (2023).

III. MATERIALS AND METHODS

The method used in this study was carried out in the following stages: preparing, planning, designing, implementing, testing, and optimizing. This method results in a standard cycle of network development and management. The flow of the method is shown in Figure 4.

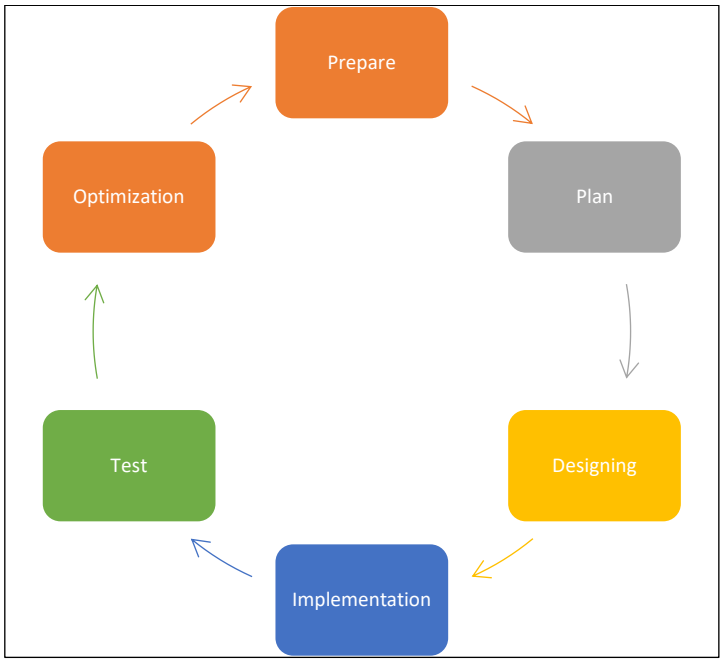


Figure 4: Research Methodology.
Source: Author, (2023).

The stages of the research are as follows:

1. **Prepare**
   At this stage, preparations are made in the form of needs analysis on cloud system services and distribution models, performance test models on cloud systems, Proxmox Virtual Environment systems, e-learning Moodle systems, and JMeter testing.
2. **Plan**
   Identify network architecture designs on Single Server-Side and Multiple Virtual Server-Side Architecture systems.
3. **Designing**
   Designing a network architecture topology system by building an e-learning Moodle system, four virtualization servers, storage clustering, a DNS server, and a web server according to testbed specifications.
4. **Implementation**
   Implement the network architecture design that has been made starting from the installation, network addressing, and service configuration stages until the system is ready for use according to the testbed parameters.
5. **Test**
   Conduct network architecture design tests that are built, which include maintenance, fault detection in the network, and monitoring performance in the implemented network architecture, using testing tools. The testing tool runs using the parameters in the test plan.
6. **Optimization**
   Repairing errors in the network, optimizing network performance, and so on for the suitability and convenience of using the network in the business processes required by the user in accordance with the test plan parameters.

III.1 TESTBED

Multiple virtual server-side architectures were designed using virtualization technology in PVE to build two different e-learning systems using Moodle. Utilizing the second reverse proxy technique, e-learning can be accessed using only a domain name and SSL certificate with the addresses https://lms.edu/lms1 for the first e-learning and https://lms.edu/lms2 for the second e-learning.

There are four virtualized servers on a physical machine, namely VM1 DNS and proxy server, VM2 web server 1, VM3 web server 2, and VM4 database server. VM3 is a replication of VM2 Web Server 1 for load balancing and high availability. Storage clustering is applied to storage media in VM2 and VM3. All virtual servers use the 64-bit Debian 10 (Buster) operating system with a command-line interface. The DNS server uses bind9, the proxy server uses Haproxy, the web server uses NGINX, and the database server uses MariaDB. The multiple virtual server-side architecture testbed design can be seen in Figure 5.

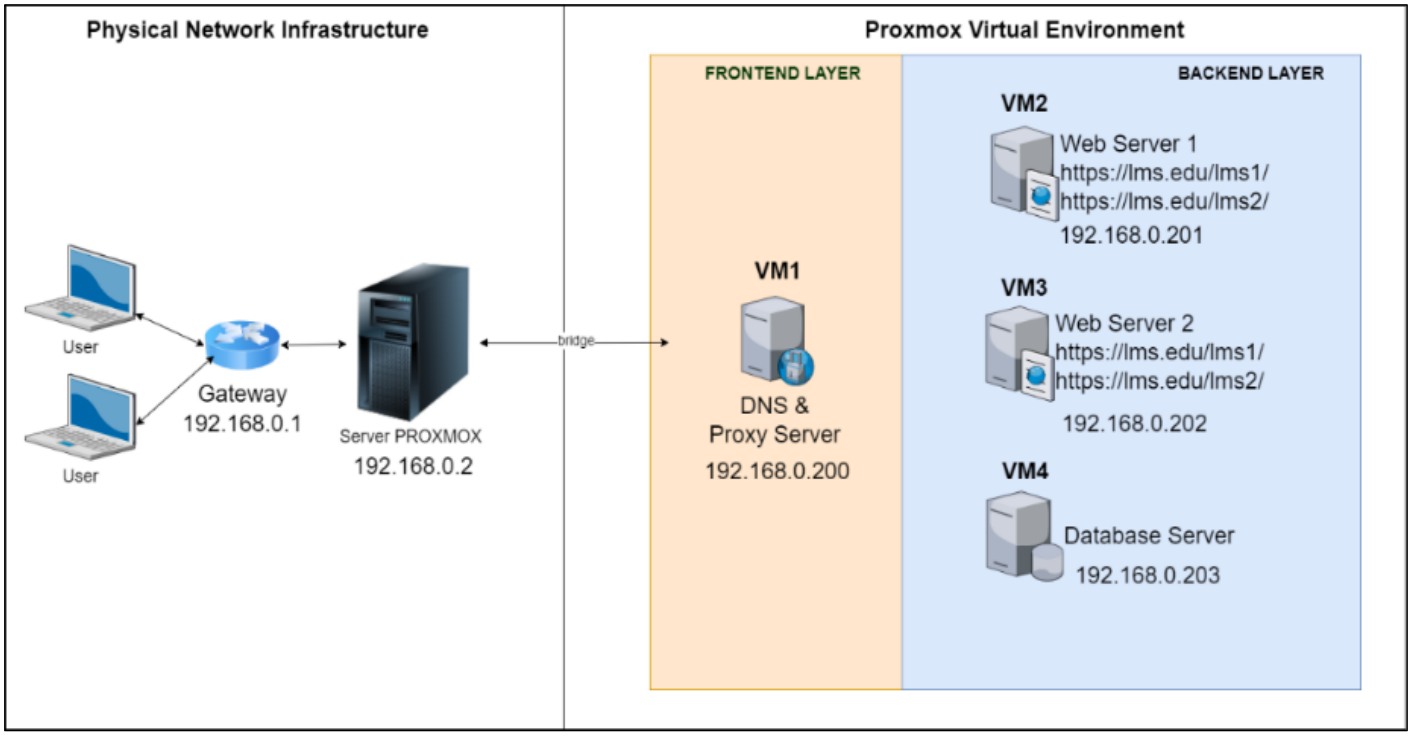


Figure 5: Testbed (Multiple Virtual Server-Side Architecture).
Source: Author, (2023).

The hardware specifications used in the multiple virtual server-side architecture can be seen in Table 1 below.

Table 1: Multiple Virtual Server-Side Architecture Specification.

Server	Processor	RAM	Storage (HDD)
Physical server (Proxmox)	AMD FX (tm)-6350 Six-Core	8GB	1TB
VM1 (DNS & Proxy)	1 Core	1 GB	8 GB
VM2 (Web Server 1)	2 Core	2 GB	8 GB
VM3 (Web Server 2)	2 Core	2 GB	8 GB
VM4 (Database Server)	1 Core	1 GB	8 GB

Source: Author, (2023).

The same case study in the form of deploying two e-learning applications and the same services on multiple virtual server-side architectures built in a testbed in the form of a single server-side architecture that uses specifications in the form of an accumulation of specifications used by virtual servers on multiple virtual server-side architectures as a comparison to analyze its performance. The testbed design on a single server-side architecture architecture can be seen in Figure 6.

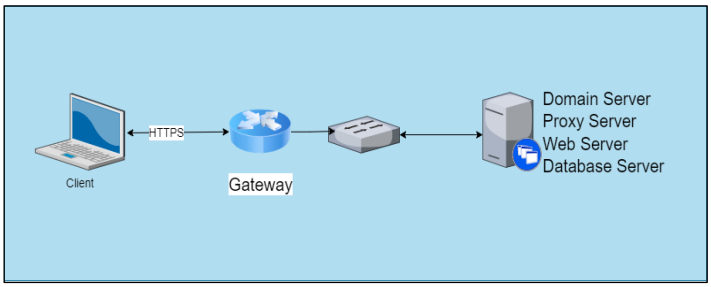


Figure 6: Testbed (Single Server-Side Architecture).
Source: Author, (2023).

The hardware specifications used in the single server-side architecture can be seen in Table 2 below.

Table 2: Single Server Architecture Specification.

Hardware	Specification
CPU	6 Core
RAM	8 GB
Storage (Harddisk)	32 GB
Network Interface Card	Gigabit Ethernet

Source: Author, (2023).

III.2 TEST PLAN

The test uses a load testing technique with the UBMP model. According to the UBMP flowchart in Figure 3, the first step is to determine test plans and test parameters. The flow of the test plan is in the form of accessing the start page, logging in, and accessing a course in e-learning. Tests were carried out on two e-learning courses, namely https://lms.edu/lms1 and https://lms.edu/lms2, simultaneously. The initial test parameters used to find the gradient value are in Table 3 below.

Table 3: Test Parameters.

No	Parameter	Value
1	Concurrent users (Threads)	10
2	Ramp-up periode	5 Threads / 1s
3	Loop	1
4	HTTP request protocol	HTTPS
5	HTTP request host	lms.edu
6	HTTP request host path	/lms1, /lms2
7	Thinking time	1s - 9s (random)

Source: Author, (2023).

The search for gradient values is carried out by adding 5 threads in each test iteration until a 5% increase in CPU is obtained. The gradient value is the difference between the threads in the first iteration and the threads in the nth iteration, which shows a 5% increase in CPU. The gradient value is used as a constant for adding threads at each iteration in the search for optimum and maximum concurrent users.

The search for the optimum value of concurrent users is carried out by adding threads at each test iteration and paying attention to the throughput value. If in the nth iteration the maximum throughput value is obtained, then the threads in the nth iteration are the optimum concurrent users. To get the maximum concurrent users, in the initial iteration of the test, the threads value is filled with the optimum concurrent users value, then updated for the next iteration with a gradient value to obtain a system availability level of up to 70%. Based on the inflection point performance index, the light, smooth, and heavy load conditions of the system can be determined as an accurate and efficient performance index.

IV. RESULTS AND DISCUSSIONS

Implementation of creating a web-based online laboratory has been carried out[6], in this study using The Networked Control System Lab (NCSLab) framework In our research, the network architecture is implemented in a cloud system using the Proxmox Virtual Environment (PVE), with tests based on the Multiple Virtual Server-Side Architecture testbed and the Single Server-Side testbed. Then a test plan is carried out based on the test parameters according to Table 3. The test is carried out based on the process flow of Availability Testing on Multiple Virtual Server-Side architectures can be seen in Figure 7. In this test, the application of reverse proxy and storage clustering not only saves system operating costs but can also increase the level of system and data availability [40].

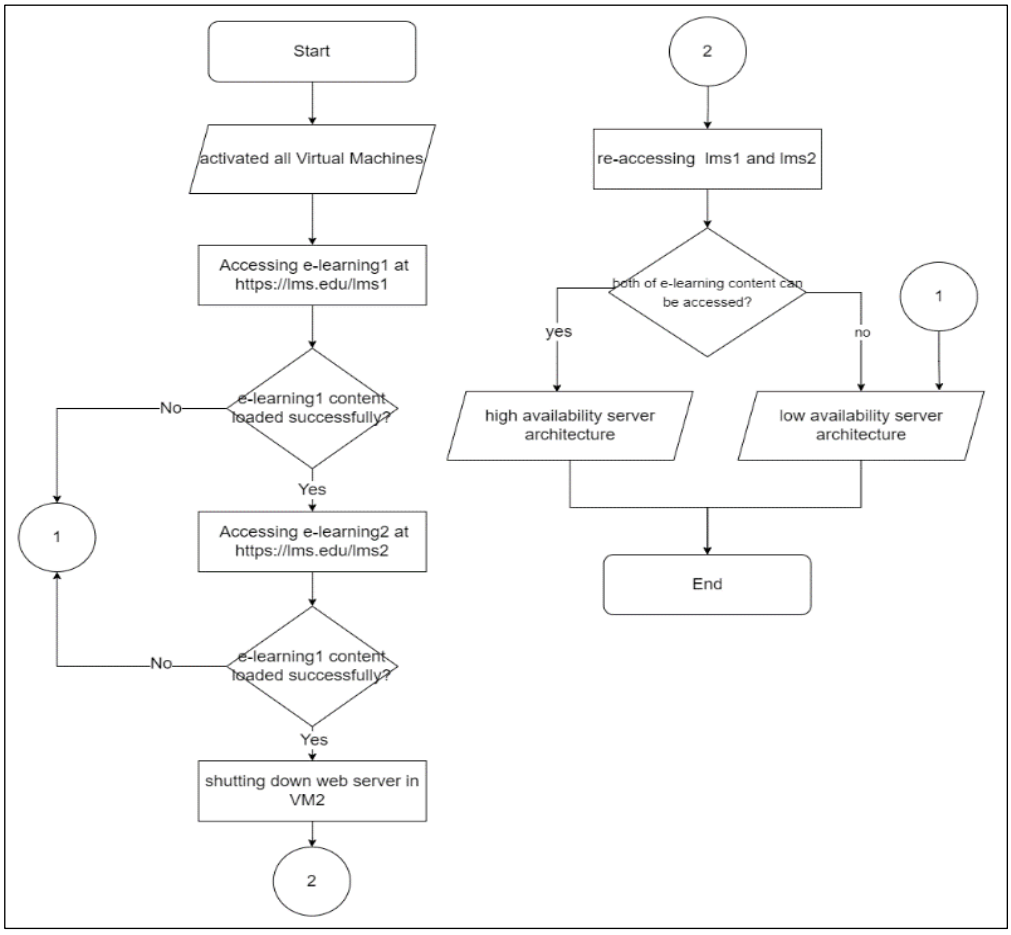


Figure 7: Availability Testing on Multiple Virtual Server-Side Architecture.
Source: Author, (2023).

Based on the testbed and testplan on the system, the gradient value obtained is 10 concurrent users[41], which is obtained by the difference in threads in the 1st and 3rd iterations with a difference in CPU usage of 5%, which can be seen in Table 4.

Table 4: CPU Usage in Gradient Value Search.

Iterations	Threads	CPU Usage				
		VM1	VM2	VM3	VM4	Average
1	10	2.1%	23.3%	24.8%	17.4%	16.9%
2	15	2.2%	29.7%	29.0%	19.1%	20.0%
3	20	2.3%	30.8%	31.3%	21.3%	21.4%
4	25	2.9%	34.5%	30.7%	27.8%	23.9%
5	30	2.7%	37.4%	38.5%	32.3%	27.7%

Source: Author, (2023).

From the results of testbed and testplan testing, it can be concluded that server virtualization with Proxmox Virtual Environment (PVE) is able to optimize hardware performance on physical server machines, then optimize server performance by dividing it into several virtual servers so that it has high efficiency in resource use. From this test, it was found that the Proxmox server was stable [42].

The test results showing that both server architectures are able to optimally handle 50 users with a maximum throughput of 4.6 s on multiple virtual servers and 4.9 s on a single server are shown in Table 5. For optimum results for concurrent users, shown in Figure 8, From this test, it was found that the value of concurrent users was appropriate [42].

Table 5: Finding Optimum Concurrent Users Value Through Maximum Throughput.

Iterations	Threads	Multiple Virtual Server		Single Server	
		Throughput	Error	Throughput	Error
1	10	2.5/s	0.0%	2.4/s	0.0%
2	20	3.3/s	0.0%	3.3/s	0.0%
3	30	4.1/s	0.0%	4.2/s	0.0%
4	40	4.1/s	1.5%	4.7/s	0.0%
5	50	4.6/s	7.0%	4.9/s	0.0%
6	60	4.5/s	11.4%	4.8/s	4.2%
7	70	4.3/s	16.4%	4.5/s	7.1%
8	80	4.0/s	16.2%	4.7/s	21.6%

Source: Author, (2023).

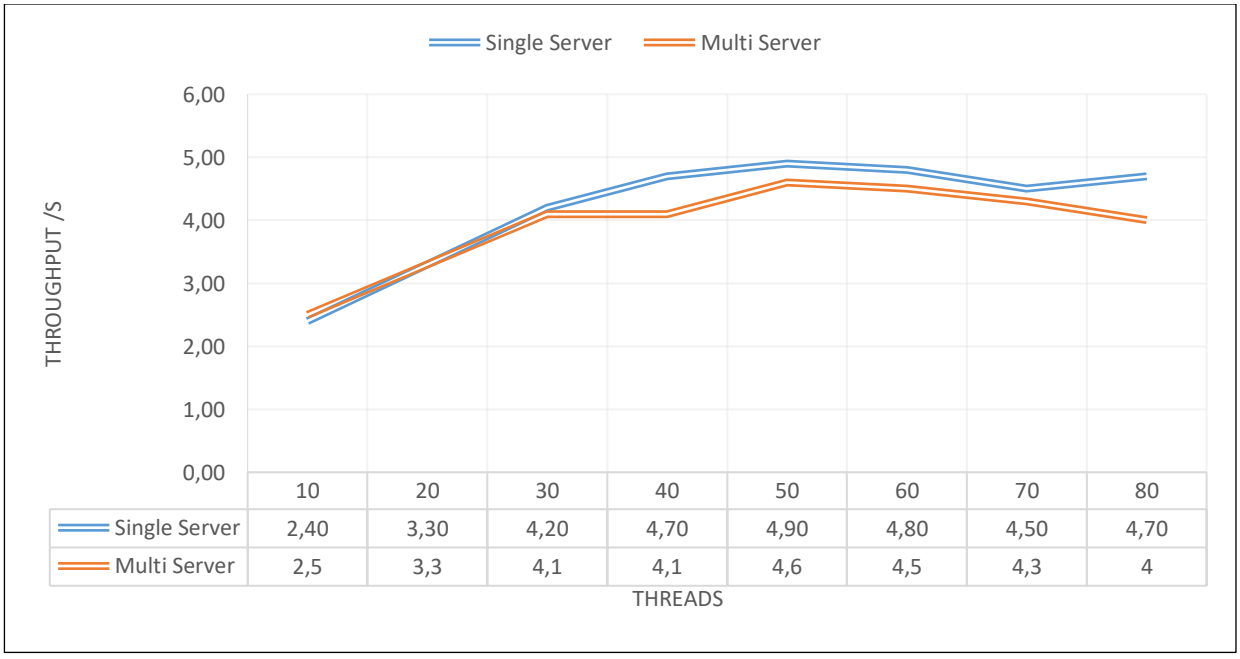


Figure 8: Optimum concurrent users.
Source: Author, (2023).

The maximum concurrent users obtained in the test show the results of the multiple virtual server-side architecture having better performance, which is able to handle a maximum of 100 users with an availability level of 80%, while the single server architecture is only able to handle as many as 80 users with an availability level of 78.4%. can be seen in Table 6. The optimum results for concurrent users are can be seen in Figure 9.

Table 6: Finding Maximum Concurrent Users Value Through The Availability.

Iterations	Threads	Multiple Virtual Server		Single Server	
		Availabilty	Error	Availabilty	Error
1	50	93.0%	7.0%	100 %	0.0%
2	60	88.7%	11.3%	95.8%	4.2%
3	70	83.6%	16.4%	92.9%	7.1%
4	80	83.8%	16.2%	78.4%	21.6%
5	90	77.5%	22.5%	68.9%	31.1%
6	100	80.3%	19.7%	67.5%	32.5%
7	110	66.9%	33.1%	64.2%	35.8%
8	120	66.8%	33.2%	62.8%	37.2%

Source: Author, (2023).

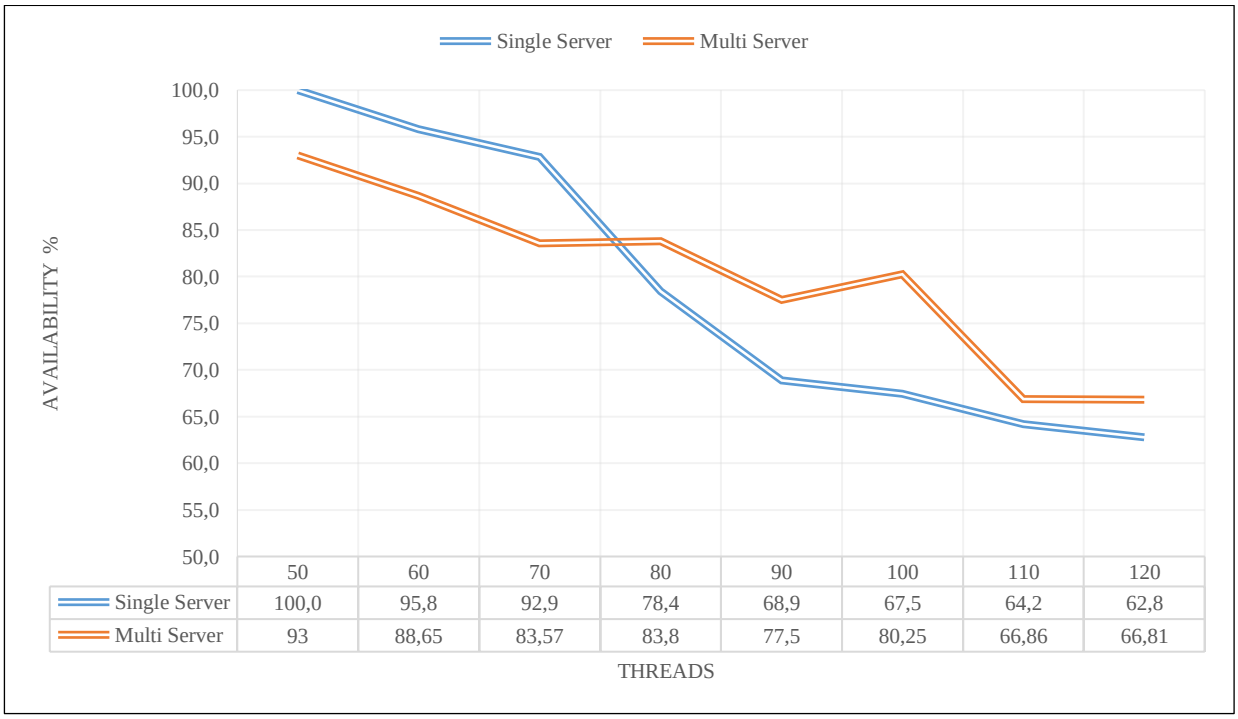


Figure 9: Maximum Concurrent Users.
Source: Author, (2023).

Based on the results obtained from the research, the performance of the multiple virtual server architecture is superior to the single server architecture by handling 20 more users in the system in the test scope when the system is tested for performance.

V. CONCLUSIONS

Based on research data, the UBMP performance test model is a testing model that is comprehensive, effective, and accurate and can be applied to systems with web-based applications implemented in Proxmox Virtual Environment (PVE). Multiple virtual server-side architectures combined with the application of reverse proxy and storage clustering techniques in research are able to optimally use existing resources and are more efficient, effective, and superior in performance than single server architectures. Multiple virtual server-side architectures can not only be applied to e-learning systems but can also be applied to other web-based application systems. Further development is needed regarding the network architecture design used in research to obtain more optimal performance and efficiency in the implementation of Proxmox Virtual Environment (PVE).

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Yuri Ariyanto.
Methodology: Yuri Ariyanto.
Investigation: Yuri Ariyanto.
Discussion of results: Yuri Ariyanto.
Writing – Original Draft: Yuri Ariyanto.
Writing – Review and Editing: Yuri Ariyanto.
Resources: Yuri Ariyanto.
Supervision: Yuri Ariyanto.
Approval of the final text: Yuri Ariyanto.

VII. REFERENCES

[1] S. P. Chung, Y. J. Lu, and Y. C. Lai, "Cloud computing with single server threshold and double congestion thresholds," ICT Express, vol. 4, no. 3, pp. 119–123, 2018, doi: 10.1016/j.icte.2017.03.002.

[2] I. Alharkan, M. Saleh, M. A. Ghaleb, H. Kaid, A. Farhan, and A. Almarfadi, "Tabu search and particle swarm optimization algorithms for two identical parallel machines scheduling problem with a single server," J. King Saud Univ. - Eng. Sci., vol. 32, no. 5, pp. 330–338, 2020, doi: 10.1016/j.jksues.2019.03.006.

[3] P. Jain, Y. Munjal, J. Gera, and P. Gupta, "Performance Analysis of Various Server Hosting Techniques," Procedia Comput. Sci., vol. 173, no. 2019, pp. 70–77, 2020, doi: 10.1016/j.procs.2020.06.010.

[4] R. Entezari-Maleki, L. Sousa, and A. Movaghar, "Performance and power modeling and evaluation of virtualized servers in IaaS clouds," Inf. Sci. (Ny)., vol. 394–395, pp. 106–122, 2017, doi: 10.1016/j.ins.2017.02.024.

[5] E. Ali, Susandri, and Rahmaddeni, "Optimizing Server Resource by Using Virtualization Technology," Procedia Comput. Sci., vol. 59, no. Iccsci, pp. 320–325, 2015, doi: 10.1016/j.procs.2015.07.572.

[6] Z. Lei, H. Zhou, S. Ye, W. Hu, and G. P. Liu, "Cost-effective server-side re-deployment for web-based online laboratories using nginx reverse proxy," IFAC-PapersOnLine, vol. 53, no. 2, pp. 17204–17209, 2020, doi: 10.1016/j.ifacol.2020.12.1748.

[7] Y. Tao and G. Chen, "An extensible universal reverse proxy architecture," Proc. - 2016 Int. Conf. Netw. Inf. Syst. Comput. ICNISC 2016, pp. 8–11, 2017, doi: 10.1109/ICNISC.2016.45.

[8] A. Rashid and A. Chaturvedi, "Virtualization and its Role in Cloud Computing Environment," Int. J. Comput. Sci. Eng., vol. 7, no. 4, pp. 1131–1136, 2019, doi: 10.26438/ijcse/v7i4.11311136.

[9] R. Kaur and S. Chopra, "Virtualization In Cloud Computing : A Review," Int. J. Sci. Res. Comput. Sci. Eng. Inf. Technol., vol. 3307, pp. 01–05, 2020, doi: 10.32628/cseit20641.

[10] V. Tiwari, A. A. Waoo, D. Akhilesh, A. Waoo, and B. Garg, "Study on Virtualization Technology and Its Importance in Cloud Computing Environment See Profile Study on Virtualization Technology and Its Importance in Cloud Computing Environment," Int. J. Creat. Res. Thoughts, vol. 8, no. 2, pp. 2320–2882, 2020, [Online]. Available: www.ijcrt.orgwww.ijcrt.org.

[11] M. K. L. Singh, W. A. T. Quijano, and G. Koneru, "Evaluation of network performance-type1 open source virtualization platforms," 2015 Int. Conf. Comput. Commun. Informatics, ICCCI 2015, 2015, doi: 10.1109/ICCCI.2015.7218073.

[12] H. Mao, "High-density information security storage method of big data center based on fuzzy clustering," Microprocess. Microsyst., vol. 81, no. November 2020, p. 103772, 2021, doi: 10.1016/j.micpro.2020.103772.

[13] A. Pérez, G. Moltó, M. Caballer, and A. Calatrava, "Serverless computing for container-based architectures," Futur. Gener. Comput. Syst., vol. 83, pp. 50–59, 2018, doi: 10.1016/j.future.2018.01.022.

[14] A. B. Prasetijo, E. D. Widianto, and E. T. Hidayatullah, "Performance comparisons of web server load balancing algorithms on HAProxy and Heartbeat," Proc. - 2016 3rd Int. Conf. Inf. Technol. Comput. Electr. Eng. ICITACEE 2016, pp. 393–396, 2017, doi: 10.1109/ICITACEE.2016.7892478.

[15] J. E. C. De La Cruz and I. C. A. R. Goyzueta, "Design of a high availability system with HAProxy and domain name service for web services," Proc. 2017 IEEE 24th Int. Congr. Electron. Electr. Eng. Comput. INTERCON 2017, 2017, doi: 10.1109/INTERCON.2017.8079712.

[16] V. A. M and P. Sonpatki, ReactJS by Example: Building Modern Web Applications with React. 2016.

[17] L. L. Salekhova, K. S. Grigorieva, and T. A. Zinnurov, "Using LMS moodle in teaching CLIL: A case study," Proc. - Int. Conf. Dev. eSystems Eng. DeSE, vol. October-20, no. May 2022, pp. 393–395, 2019, doi: 10.1109/DeSE.2019.00078.

[18] A. Villar-Martinez, L. Rodriguez-Gil, I. Angulo, P. Orduna, J. Garcia-Zubia, and D. Lopez-De-Ipina, "Improving the Scalability and Replicability of Embedded Systems Remote Laboratories through a Cost-Effective Architecture," IEEE Access, vol. 7, pp. 164164–164185, 2019, doi: 10.1109/ACCESS.2019.2952321.

[19] S. Kanthavar, S. Simeen, M. Chawla, and S. Sarayu, "Design of an Architecture for Cloud Storage to Provide Infrastructure as a Service (IaaS)," 2017 14th IEEE India Counc. Int. Conf. INDICON 2017, 2018, doi: 10.1109/INDICON.2017.8488000.

[20] F. Zhang, Y. Liu, J. Mao, M. Zhang, and S. Ma, "User behavior modeling for Web search evaluation," AI Open, vol. 1, no. March, pp. 40–56, 2020, doi: 10.1016/j.aiopen.2021.02.003.

[21] H. H. Li, X. R. Li, H. Wang, J. Zhang, and Z. X. Jiang, "Research on cloud performance testing model," Proc. IEEE Int. Symp. High Assur. Syst. Eng., vol. 2019-Janua, no. January 2019, pp. 179–183, 2019, doi: 10.1109/HASE.2019.00035.

[22] A. F. Wicaksono and A. Moffat, "Metrics, User Models, and Satisfaction," pp. 654–662, 2020.

[23] P. He, J. Qiu, and B. Zhai, "Study on the integration of cloud computing and moodle learning platform," Proc. 2015 IEEE Int. Conf. Commun. Softw. Networks, ICCSN 2015, pp. 367–371, 2015, doi: 10.1109/ICCSN.2015.7296185.

[24] C. De Medio, C. Limongelli, F. Sciarrone, and M. Temperini, "MoodleREC: A recommendation system for creating courses using the moodle e-learning platform," Comput. Human Behav., vol. 104, p. 106168, 2020, doi: 10.1016/j.chb.2019.106168.

[25] M. Zabolotniaia, Z. Cheng, E. M. Dorozhkin, and A. I. Lyzhin, "Use of the LMS Moodle for an effective implementation of an innovative policy in higher educational institutions," Int. J. Emerg. Technol. Learn., vol. 15, no. 13, pp. 172–189, 2020, doi: 10.3991/ijet.v15i13.14945.

[26] W. Fernando, "Moodle quizzes and their usability for formative assessment of academic writing," Assess. Writ., vol. 46, no. September, p. 100485, 2020, doi: 10.1016/j.asw.2020.100485.

[27] D. Arnaldy and T. S. Hati, "Performance Analysis of Reverse Proxy and Web Application Firewall with Telegram Bot as Attack Notification on Web Server," 2020 3rd Int. Conf. Comput. Informatics Eng. IC2IE 2020, pp. 455–459, 2020, doi: 10.1109/IC2IE50715.2020.9274592.

[28] L. H. Pramono, R. C. Buwono, and Y. G. Waskito, "Round-robin algorithm in HAProxy and nginx load balancing performance evaluation: A review," 2018 Int. Semin. Res. Inf. Technol. Intell. Syst. ISRITI 2018, no. July, pp. 367–372, 2018, doi: 10.1109/ISRITI.2018.8864455.

[29] K. Kritikos and P. Skrzypek, "Simulation-as-a-service with serverless computing," Proc. - 2019 IEEE World Congr. Serv. Serv. 2019, vol. 2642–939X, pp. 200–205, 2019, doi: 10.1109/SERVICES.2019.00056.

[30] L. Hernandez, G. Jimenez, A. Pranolo, and C. U. Rios, "Comparative Performance Analysis Between Software-Defined Networks and Conventional IP Networks," Proceeding - 2019 5th Int. Conf. Sci. Inf. Technol. Embrac. Ind. 4.0 Towar. Innov. Cyber Phys. Syst. ICSITech 2019, pp. 235–240, 2019, doi: 10.1109/ICSITech46713.2019.8987493.

[31] K. Arjunan and C. N. Modi, "An enhanced intrusion detection framework for securing network layer of cloud computing," ISEA Asia Secur. Priv. Conf. 2017, ISEASP 2017, 2017, doi: 10.1109/ISEASP.2017.7976988.

[32] J. Yang and Y. Lan, "A performance evaluation model for virtual servers in KVM-based virtualized system," Proc. - 2015 IEEE Int. Conf. Smart City, SmartCity 2015, Held Jointly with 8th IEEE Int. Conf. Soc. Comput. Networking, Soc. 2015, 5th IEEE Int. Conf. Sustain. Comput. Communic, pp. 66–71, 2015, doi: 10.1109/SmartCity.2015.49.

[33] Y. Ariyanto, B. Harijanto, A. Setiawan, S. Adhisuwignjo, and E. Rohadi, "Integration of digital library server with Service Oriented Architecture (SOA) based on cloud computing using proxmox server," J. Phys. Conf. Ser., vol. 1402, no. 7, 2019, doi: 10.1088/1742-6596/1402/7/077054.

[34] S. Grabovsky, P. Cika, V. Zeman, V. Clupek, M. Svehlak, and J. Klimes, "Denial of Service Attack Generator in Apache JMeter," Int. Congr. Ultra Mod. Telecommun. Control Syst. Work., vol. 2018-November, pp. 1–4, 2019, doi: 10.1109/ICUMT.2018.8631212.

[35] P. Cika, S. Grabovsky, V. Zeman, and V. Clupek, "Network Emulator of Transmission Parameters of Data Networks," Int. Congr. Ultra Mod. Telecommun. Control Syst. Work., vol. 2018-November, no. 1, pp. 1–6, 2019, doi: 10.1109/ICUMT.2018.8631254.

[36] S. Pradeep and Y. K. Sharma, "A Pragmatic Evaluation of Stress and Performance Testing Technologies for Web Based Applications," Proc. - 2019 Amity Int. Conf. Artif. Intell. AICAI 2019, pp. 399–403, 2019, doi: 10.1109/AICAI.2019.8701327.

[37] O. Hkdylru et al., "Cloud Storage Behavior Analysis Using Time Series Clustering," pp. 90–95, 2018.

[38] Z. Tang, S. Sha, J. Zhang, Z. Li, H. Peng, and H. Du, "WebGlusterFS2.0: A Web-based Administration Tool for GlusterFS with Unattended Deployment and Automatic Configuration of Xlator," 2019 Comput. Commun. IoT Appl. ComComAp 2019, pp. 276–281, 2019, doi: 10.1109/ComComAp46287.2019.9018744.

[39] Q. Ye, W. Hu, and H. Zhou, "Implementation of WebVR-based laboratory for control engineering education based on NCSLab framework," Chinese Control Conf. CCC, pp. 7880–7885, 2017, doi: 10.23919/ChiCC.2017.8028601.

[40] Z. Yang and X. Huang, "Dynamic Configuration of Reverse Proxy Cache based on Multi-Dimensional Time Series Prediction of Visit Traffic," pp. 237–240.

[41] H. H. Li, X. R. Li, H. Wang, J. Zhang, and Z. X. Jiang, "Research on cloud performance testing model," Proc. IEEE Int. Symp. High Assur. Syst. Eng., vol. 2019-Janua, no. 2015, pp. 179–183, 2019, doi: 10.1109/HASE.2019.00035.

[42] L. Chen, W. Huang, A. Sui, D. Chen, and C. Sun, "The online education platform using Proxmox and noVNC technology based on Laravel framework," Proc. - 16th IEEE/ACIS Int. Conf. Comput. Inf. Sci. ICIS 2017, pp. 487–491, 2017, doi: 10.1109/ICIS.2017.7960041.

Journal of Engineering and Technology for Industrial Applications

ISSN ONLINE: 2447-0228

ITEGAM-JETIA

Manaus, v.9 n.44, p. 35-48. Nov/Dec, 2023

DOI: https://doi.org/10.5935/jetia.v9i44.1010

RESEARCH ARTICLE OPEN ACCESS

LOGISTICS MANAGEMENT: A FUTURE PERSPECTIVE ON LOGISTICS PROCESSES WITH THE APPLICATION OF THE 5S METHOD AT BRAMAM COMPANY IN PARINTINS, AMAZONAS

Roberta Pontes da Costa*[1], Thiago Mendonça de Souza[2], Bruna Lorrayne Vasconcelos Barros[3], Vanessa Coelho da Silva[4], Emanuel Kedson da Silva Freitas[5] and Aderli Vasconcelos Simões[6]

[1, 2, 3] Department of Management Process Technology, Faculty of Technology – SENAC, Manaus, Amazonas, Brazil.
[4, 5] Department of Intellectual Property, Technology Transfer and Innovation - PROFINIT/UEA, State University of Amazonas – UEA, Manaus, Amazonas, Brazil.
[6] Department of Administration, State University of Amazonas – UEA, Manaus, Amazonas, Brazil.

[1] http://orcid.org/0009-0006-1047-8149, [2] http://orcid.org/0009-0008-3105-1149, [3] http://orcid.org/0009-0006-6542-0446,
[4] http://orcid.org/0009-0007-0006-3705, [5] http://orcid.org/0009-0002-9803-7137, [6] http://orcid.org/0009-0008-0822-3424,

Email: *robertinpontes@gmail.com, thiagobramamm@gmail.com, brunanarros26825@gmail.com, vcsilva@uea.edu.br, kedsonfreitas2015@gmail.com, asimoes@uea.edu.br

ARTICLE INFO

Article History
Received: December 13th, 2023
Revised: December 26th, 2023
Accepted: December 27th, 2023
Published: December 30th, 2023

Keywords:
5S Program,
Logistics Sector,
Continuous Improvement.

ABSTRACT

This project required a study of the 5S program, involving commercialization and logistics in the municipality of Parintins. In this context, the implementation was carried out at Bramam, a beverage industry located in this municipality. The aim was to improve the efficiency and organization of its logistics operations by implementing an improvement project based on the 5S program, a widely used Japanese methodology for promoting organization and discipline in work environments. The general objective of the 5S project at Bramam was to promote a cultural change among employees, focusing on continuous improvement, through the implementation of the program's five principles: sorting, setting in order, systematic cleaning, standardizing, and sustaining. These principles were applied in the logistics sector, assessed in three departments: warehouse, trucks, and forklifts, aiming to enhance the use, organization, cleanliness, maintenance, and discipline in the use of these machines, seeking positive results in terms of efficiency, productivity, safety, and quality. With this research, we expect to obtain relevant insights and conclusions that can contribute to understanding the effectiveness of the 5S program in the logistics sector of the beverage company under study. The project is implemented with results that can be used as a basis for the implementation or improvement of the 5S program in other organizations, aiming to enhance the quality of services and operational performance in the workplace.

I. INTRODUCTION

Logistics management is an area that has been increasingly developing, aiming to improve logistics processes to ensure greater efficiency and cost reduction. In the context of the Parintins market, logistics plays a vital role in product availability, especially during the Folk Festival when demand significantly increases, requiring enhanced management in this process.

In this context, the application of the 5S method can be an excellent tool to improve the organization and availability of materials and equipment in companies. The 5S method is a management philosophy that aims to improve process quality, increase productivity, and consequently, enhance the efficiency of the company. Applying the 5S method in logistics management can bring benefits such as reduced waiting times, decreased waste, improved product quality, and optimization of storage space.

Moreover, it allows for better product identification and greater agility in the separation process for delivery.

In this regard, this research aims to analyze the application of the 5S program in the logistics sector of the company "Bramam Comércio de Bebidas Limitadas" located in the municipality of Parintins. Specifically, we seek to understand the company's situation and identify factors that influence the quality of logistics services. Additionally, we intend to conceptualize the positive aspects of the 5S program and demonstrate its applicability in logistics processes.

The methodology used in this research is qualitative, involving the collection of information that supported the identification and resolution of problems related to the implementation of the 5S program in the beverage company in Parintins. To achieve this, we analyzed sequences of procedures that were subjected to systematic evaluation, aiming to understand the impacts on the development and progress of program implementation.

In the planning and strategy of the study, a feasibility analysis of the project was carried out, considering the time required for the project's stages, as well as the bureaucratic procedures required to obtain authorization from the company for the research to be conducted satisfactorily.

Considering the feasibility of the research, a literature review was conducted to theoretically underpin the study, seeking literary sources that would support the theoretical foundations of the 5S program. Subsequently, the study location and research procedures were planned, as well as the legal procedures for its implementation, including authorization for experiments, definition of execution time, resources used, and participant profile and characterization.

This research was motivated by the need to gain in-depth understanding of the process of implementing the 5S program in a beverage company located in Parintins. The aim is to analyze the stages and results obtained throughout this process in detail, aiming to contribute to the proper functioning of the business and generate positive results in terms of profitability.

It is important to emphasize that this research proposal seeks not only to understand the application of the 5S program but also to contribute to improving the company's performance in terms of operational efficiency and service quality. The 5S program is widely used in many organizations around the world, proven to be effective in promoting a culture of organization and discipline in the workplace.

In this project, the 5S program was chosen as a research source due to its relevance and applicability in the logistics sector of the beverage company under study. Through a careful analysis of the program implementation stages, the results obtained, and the impacts on the company's development and progress, we aim to identify the positive aspects of this methodology and its applicability in logistics processes.

II. THEORETICAL FRAMEWORK

II.1 QUALITY MANAGEMENT

Quality management is one of the main managerial methods used today, given the need to seek proper training and management of human resources in companies. [1] states that the new development ideology assumes that producing with better quality means producing with greater productivity, which results in less waste, less work, and consequently, lower costs.

In the current market, constantly seeking cost reduction is essential, and for this, it is necessary to manage the company's resources effectively through quality management, focusing on processes and products, aiming to achieve positive results. To do so, understanding the needs of each department or sector of the organization is crucial for any enterprise.

Defining quality management is a challenging task, as over time this approach has adapted to market changes. Initially, quality management was viewed from the perspective of inspection, using measurement instruments, with the premise of focusing only on results, not on processes. However, today, quality management is focused on strategic quality management, with a concern for competing in the market and satisfying both customer and market needs.

In a broader sense, the concept of total quality management or quality management has come to mean a management model that seeks organizational efficiency and effectiveness. (JUNIOR, 2003) [2].

Quality management went through four significant periods in its history. The first was the era of inspection, developed by craftsmen and artisans who worked informally but took the first steps toward operational quality management, presenting "rudimentary standards of quality for goods and services and basic levels of labor performance, with the determination of general conditions of human work" [3]. This era became known as the Era from the Field to the Market, beginning at the turn of the 20th century, with agrarian economics as the main theoretical influence, and its main concern was transportation.

The second period was marked by statistical quality control, where the inspection process had already been improved, as the industrial process had been established and its growth made manual production verification impractical. The publication of W. A. Shewhart's work "Economic Control of Quality of Manufactured Product" in 1931 represented a milestone in the quality movement, giving it a scientific character. In this period, quality assurance emerged, where quality was from being a narrow discipline based solely on factory production, it has broader implications for management. The goal in this era was to separate the good from the bad products through statistical sampling, starting with mass production and reaching its peak during World War II when there was a need to precisely control the quality of millions of items manufactured for the war effort. “The objective now is to separate the good from the bad products through statistical sampling. This era began with mass production and saw the emergence of the quality control department in company structures”. [4].

Advancements in quality occurred with the rapid growth of the industry, even with unskilled labor, which affected the quality levels of products/services. The third era of quality takes a more comprehensive approach, going beyond just product quality and managing all members of the organization, seeking proactivity as a guarantee of positive results in problem-solving.

The Era of Quality Assurance realizes that all processes and aspects affecting quality must be considered, including suppliers, and it adopts a broader perspective. During this period, a consolidated management of supply transportation, distribution, storage, inventory control, and material handling activities emerged.

In the fourth era, we have Total Quality Management (TQM), which from the 1980s onwards places the customer as one of the main focuses. The concern is no longer just on the factory floor but seeks to understand the customer as a fundamental part of the process and develop strategies to attract and satisfy the customer. The development of quality management in each era aims to identify and solve market performance challenges, proposing solutions to improve company performance.

II.1.2 Quality Tools

With the advent of globalization, the perspective of commerce has changed significantly. Competition is no longer limited to the local market but rather global competition, where any company can offer a similar product. The differentiator has become which company the customer will feel motivated to buy from and how to earn their loyalty. As a result, quality has shifted from being merely a differentiator to becoming a requirement for all companies wishing to stay active in the market.

Quality management has become essential for companies to face this fierce competition. There are several quality management tools used to ensure continuous process improvement and customer satisfaction. Some of the key tools include:

- PDCA (Plan-Do-Check-Act): It is a cycle of continuous improvement that involves planning, executing, checking, and acting to implement changes and improvements in processes.
- Ishikawa Diagram (also known as a cause-and-effect diagram or fishbone diagram): It is a visual tool that helps identify and analyze the causes of a problem, allowing for the search for suitable solutions.
- Flowcharts: These are diagrams that graphically represent the steps of a process, helping to identify bottlenecks, rework, and improvement opportunities.
- Brainstorming: It is a group idea generation technique, stimulating creativity and involving everyone in identifying solutions.
- 5W2H (What, Why, Where, When, Who, How, How much): It is a tool that helps define actions clearly and in detail, identifying what, why, where, when, who, how, and how much will be done.

These are just some of the many tools available in quality management. The proper use of these tools can help companies identify and correct problems, optimize processes, and achieve high levels of quality in their products and services, which is essential to meet customer expectations and remain competitive in the globalized market.

II.1.3 5S Program

The 5S program originated in Japan in the mid-1950s, shortly after World War II, as a strategy to help companies recover from the post-war crisis and make significant advancements in quality management.

The 5S correspond to five Japanese words that represent objectives for change in organizational processes. Each word carries a specific objective for improving functions. They are: Seiri (sense of utilization), Seiton (sense of organization), Seiso (sense of cleanliness), Seiketsu (sense of health/hygiene), and Shitsuke (sense of self-discipline) [5].

II.1.2.1 SEIRI – Sense of Utilization

This involves organizing spaces within the company to facilitate the search for files or any other elements, identifying and organizing everything for easy access for anyone. When it comes to this sense, the priority is to catalog all items in the department to organize them into folders and cabinets, facilitating access and streamlining processes. [6].

II.1.2.2 SEITON – Sense of Organization

The sense of organization aims to organize the work environment by putting each element in its proper place. When dealing with the professional environment, it is important for each department within a company to have control over each situation, as each department receives demands that need to be addressed on time for the smooth operation of the process. [7].

II.1.2.3 SEISO – Sense of Cleanliness

Maintaining a hygienic work environment involves eliminating potential factors contributing to dirt accumulation, resulting in numerous benefits such as improved physical and mental health, improved internal and external workplace image, reduced maintenance, among others. [8].

II.1.2.4 SEIKETSU – Sense of Health

Providing a workplace favorable to mental and physical health, seeking to eliminate factors that may negatively affect employees' performance. The initial results of the health sense, according to [9], are important to note that a healthy work environment allows for improved productivity because employees feel comfortable performing their duties. The traditional approach of supervising employees can generate stress and hinder task execution.

II.1.2.5 SHITSUKE – Sense of Self-discipline

Incorporating defined standards and procedures into daily life by committing to maintaining the senses in the work routine. The sense of self-discipline suggests that employees should be knowledgeable about the company's rules and regulations. Therefore, employees can control their actions, avoiding conflicts. Knowing only individual responsibilities is not enough; a deeper understanding of the company's objectives is required. [7].

The 5S program is an efficient method in the current scenario where companies are constantly striving for improvement. It emerges as a way to achieve good results with low costs. According to [10], "The implementation of 5S results in improvements in quality, organization, and optimization in any company, regardless of its industry or size. It is a philosophy, a new culture that requires the commitment and participation of work teams."

Figure 1 - 5S Scheme.
Source: [11].

II.2 LOGISTICS IN ORGANIZATIONS

Meeting the demands of the consumer market and adhering to required standards involves greater organizational capacity in materials management. Thus, the ability to offer quality goods and services to customers will be greater. However, to achieve this goal, a company must develop appropriate planning tailored to its goals and effective control of resources. Adequate planning for organization is tied to the logistics sector, which, in general, is responsible for delivering the product with quality, at the right time, and at an affordable price.

Logistics, according to the Council of Logistics Management [12], is seen as a process of planning and effectively controlling the flow and storage, capable of managing costs from raw materials to inventory, managing product information from its origin until the point of consumption with the proposal to deliver a quality product that meets the demands of its customers. For a long time, logistics was mistakenly understood as a process of transporting products. However, according to [13], it is a science that aims to solve problems from input to the production sector, still concerned with finished and semi-finished distribution issues and other warehouse facilities, information processing, including spatial and temporal constraints. “Logistics has evolved from a narrower focus on the physical distribution of materials and goods to a broader scope, considering the entire supply chain and activities such as purchasing, material management, and distribution” [14].

The [15] theorizes that the primary concept of logistics is the strategic management of movement, warehousing, product organization, and resources to achieve profitability with low costs. In other words, the interrelation of operational sectors should share the same premises to achieve profit.

Organizations encompass various areas that need to function properly and in common agreement. As we know, managing a business requires not only delivering the service/product but also aligning with human principles that provide dignity to workers, administrative principles of planning, organizing, directing, and controlling, and environmental principles related to product quality and its ecological treatment. In a globalized world and facing an increasingly competitive market, it is a requirement that every business is seeking to update its practices. Moreover, after the scenario of the COVID-19 pandemic, significant investments in the convenience of buying and receiving products quickly and with higher quality were observed.

Amid these sudden changes in the market, it is of utmost importance to be in constant transformation. It's not about changing all the time but seeking methods to bring the consumer closer to the offered product. This means presenting the product at the right time with the right price.

To meet the demands of the consumer market and adhere to required standards, it is essential for companies to have efficient management of their logistics operations. A well-structured and managed organization has a greater ability to offer quality goods and services to customers. To achieve this goal, it is essential to develop appropriate planning aligned with the company's goals and effective control of available resources.

Proper planning is directly related to the logistics sector, which is responsible for ensuring the delivery of the product with quality, on the correct schedule, and at an affordable price. Logistics encompasses various activities, such as transportation, warehousing, inventory management, procurement management, and distribution, among others. Efficient logistics management contributes to cost reduction, increased productivity, and improved service to customers.

Furthermore, logistics also plays a strategic role in the company, contributing to competitiveness in the market. A well-structured and managed supply chain allows for greater agility in operations, flexibility to deal with market changes, and better utilization of available resources. Logistics can also help identify improvement opportunities through the analysis of performance indicators and process monitoring.

In this context, investing in technology, automation, and integration of logistics processes is crucial to optimize operations and ensure the efficiency of the supply chain. Additionally, it is essential to promote a culture of continuous improvement, encouraging employee training and teamwork to identify optimization opportunities and implement corrective actions.

III. MATERIALS AND METHODS

The methodology of this research consists of applying scientific procedures and techniques to seek answers to the proposed objectives. Following the definition of [16], the methodology examines, describes, and evaluates research methods and techniques that allow for the collection and processing of information to address and solve problems.

In this sense, this research is of a qualitative nature, as it considers the researcher as the main element for data collection. According to [17], qualitative research does not have a quantitative character but seeks to understand situations. This approach was chosen because it is favorable to the analysis of the implementation of the 5S program in a beverage company in Parintins, which is the focus of this research.

Based on the described procedures, it can be affirmed that the type of research adopted is a field case study since the

researcher leaves their environment in search of answers. Data collection will be conducted under natural conditions where phenomena occur, without interventions or handling by the researcher, using intensive direct observation and structured interviews as data collection techniques.

To conduct this qualitative research, data collection strategies were adopted to support the resolution of the problems identified in the implementation process of the 5S program. Additionally, a feasibility study of the project was conducted, considering the time required for the development of the stages, as well as the bureaucratic procedures for obtaining authorization from the company to conduct the research.

Literature review was a fundamental step to theoretically support the research, seeking references and literary means to underpin the theoretical foundations of the 5S program and its application in the logistics area. Planning and study strategies were carefully developed, including the definition of the research location, the legal procedures for conducting the research, the execution time, the resources used, and the characterization of the participants.

With the completion of this research, it is expected to obtain relevant insights and conclusions that can contribute to understanding the effectiveness of the 5S program in the logistics sector of the beverage company under study. These results can be used as a basis for the implementation or improvement of the 5S program in other organizations, aiming to enhance the quality of services and operational performance in the workplace.

The research on the 5S program encompasses different areas, but it is implemented in the Bramam company in the logistics sector. The research aims to explore the benefits, challenges, impacts, and best practices related to the implementation and maintenance of the 5S program.

In the context of data collection, various instruments can be used to obtain information about the application and effectiveness of the 5S program.

To achieve the results, the research followed the following procedures:

i. Feasibility Study: In this stage, the feasibility of the project was assessed, including an analysis of the available time for the study's implementation and the company's authorization for research execution.

ii. Literature Review: Following the feasibility analysis, a literature review on the chosen topic was conducted to provide a foundation for the research project.

iii. Study Planning: During the study planning phase, various activities were organized, including the definition of the research location, obtaining permission to conduct the experiment, determining the experiment's duration, resource allocation, participant characterization, observational study, and the development of post-test questionnaires.

iv. Study Execution: In this stage, the planned activities from the previous stage were executed, involving intensive direct observation and structured interviews in the logistics sector of the Bramam company, where the 5S program will be implemented.

IV. DISCUSSION OF RESULTS

The implementation of the 5S program at Bramam company was a strategic initiative to improve internal processes' organization, cleanliness, and efficiency. However, during the program's implementation, one of the main challenges faced was the self-discipline of employees.

Self-discipline is one of the fundamental principles of the 5S program, involving the ability to maintain consistent habits of organization, cleanliness, and standardization in the workplace. However, not all employees were accustomed to rigorously following the established procedures, which created difficulties in program execution.

To overcome this challenge, Bramam company implemented a series of actions, such as specific training and awareness sessions regarding the importance of self-discipline in the context of the 5S program. Awareness meetings and practical activities were conducted to demonstrate to employees the benefits and positive results that could be achieved through the adoption of self-discipline.

Furthermore, mechanisms for monitoring and tracking the 5S program were established, with regular inspections to verify compliance with established procedures and identify improvement opportunities. Employees were encouraged to share ideas and suggestions to enhance the program and make it more effective. The results will now be presented according to each observed sector:

IV.1 5S PROGRAM IN THE WAREHOUSE

The 5S program is a management methodology aimed at promoting organization, cleanliness, standardization, discipline, and continuous improvement in the workplace. At Bramam Parintins, the implementation of the 5S program in the warehouse yielded both positive and negative points, as described below:

IV.1.1 Positive Points

1. Improved Organization: The implementation of the 5S program in Bramam Parintins' warehouse resulted in a significant improvement in storage space organization. Clear standards for arrangement, material identification, and specific locations for each type of item were established. This facilitated the location and access to materials, reducing search time and improving operational efficiency

2. Increased Productivity: With a more organized and clean warehouse, Bramam Parintins' employees started working more efficiently and agilely. The reduction in time spent searching for materials, the standardization of storage processes, and the elimination of unnecessary or obsolete items contributed to increased warehouse productivity.

3. Safer Work Environment: The 5S program also brought improvements to workplace safety in Bramam Parintins' warehouse. The elimination of unnecessary or poorly-maintained materials and objects reduced the risk of accidents and falls. Additionally, regular cleaning and standardization of storage processes contributed to creating a safer and healthier work environment.

IV.1.2 Negative Points

1. Resistance to Change: The implementation of the 5S program may have faced resistance from employees, especially those who were accustomed to working in a disorganized manner without clear standards.

2. Lack of Self-Discipline: Self-discipline, one of the fundamental principles of the 5S program, may have been a negative point in its implementation in Bramam Parintins' warehouse.

3. Need for Constant Monitoring and Follow-up: Maintaining the 5S program requires constant monitoring and follow-up to ensure adherence to established procedures.

IV.2 5S PROGRAM IN THE TRUCKS

IV.2.1 SEIRI

The first "S" of the 5S program is "Seiri," also known as "Sort" or "Selection." It is the initial stage of the 5S program, involving the identification and elimination of unnecessary, obsolete, excessive, or unused items in the workplace to create a clean, organized, and efficient space. For a better understanding of the results obtained, the tables below will explicitly show which employee conducted the assessment and their assessment in percentages according to the questions asked:

Table 1 – Questions Asked to Employees and Responses Obtained.

SELECTION				
1	**2**	**3**	**4**	**5**
Is the cab free of products, containers, and unnecessary items?	Is the vehicle's documentation in an appropriate location, within a single folder, easily accessible, and known to all?	Are the cabin upholstery in good condition (without tears and exposed metal)?	Is the tracking device in good condition (clean, without cracks in the screen and/or chips)?	Are the bays in good condition (without tears, rust, and/or sharp edges)?
OK	OK	OK	OK	OK
OK	OK	OK	OK	**NOK**
OK	OK	OK	OK	OK
OK	OK	OK	OK	OK
OK	OK	OK	OK	OK
OK	OK	OK	OK	OK
OK	OK	OK	OK	**NOK**

Source: Authors, (2023).

This shows that Bramam Parintins company has achieved positive results in the implementation of the first "S" (Seiri) of the 5S program. The high score of 100% in almost all assessed items indicates that the company has excelled in organizing and selecting necessary items in the workplace. However, it is important to note that the fifth question, which had more negative situations, may indicate that there are still areas for improvement in the company regarding the selection and removal of unnecessary items. It is necessary to identify specific negative situations and work to correct them to improve the implementation process of the first "S" and achieve even better results in Table 2.

Table 2 - Evaluator description.

Month	**S**	**Evaluator**
Feb	100,00%	Evaluator II
Feb	100,00%	Evaluator II
Feb	100,00%	Evaluator II
Feb	100,00%	Evaluator II
Feb	100,00%	Evaluator II
Feb	100,00%	Evaluator II
Feb	80,00%	Evaluator II

Source: Authors, (2023).

Question 3, which is not being executed according to the evaluator's perspective, is an aspect that needs to be carefully evaluated and considered by Bramam Parintins company. It is important to understand the reasons why this question is not being met and take appropriate corrective actions to ensure that all elements of the first "S" (Seiri) of the 5S program are fully implemented.

The overall satisfaction presented by Evaluator 2 can be a positive indication that the company is succeeding in other areas, but the identification of a gap in question 3 should be treated with attention, as presented in Table 3:

Table 3 - Questions asked to employees and answers obtained.

SELECTION				
1	**2**	**3**	**4**	**5**
Is the cabin free of products, containers and unnecessary items?	Is the vehicle documentation in a suitable location, in a single folder, easily accessible and known to everyone?	Is the cabin upholstery in good condition (no tears or exposed iron)?	Is the tracking device in good condition? (clean, no screen cracks and/or chips)	Are the stalls in good condition (no tears, rust and/or edges)?
OK	OK	OK	OK	OK
OK	OK	OK	OK	OK
OK	OK	OK	OK	OK
OK	OK	OK	OK	OK
OK	OK	OK	OK	OK
OK	OK	OK	OK	OK
OK	OK	**NOK**	OK	OK

Source: Authors, (2023).

IV.2.2 SEITON

The second "S" of the 5S program is "Seiton," which refers to organization, specifically the efficient and functional organization of necessary items. It is important to remember that the 5S program is a management methodology that seeks to improve organization and cleanliness in the workplace, promoting continuous improvement and efficiency in operations.

According to the tables below: The evaluation by Evaluator 1 showed that Bramam Parintins company achieved a percentage of 80% in the truck's organization stage, indicating a critical assessment regarding the vehicle's organization. This assessment may indicate some negative points in the execution of the second "S" of the 5S program in the company.

Table 4 – Description of the Evaluator.

Month	O	Evaluator
Jan	80,00%	Evaluator I
Jan	80,00%	Evaluator I
Jan	80,00%	Evaluator I
Jan	80,00%	Evaluator I
Jan	80,00%	Evaluator I
Jan	80,00%	Evaluator I
Jan	60,00%	Evaluator I

Source: Authors, (2023).

Table 5 - Questions and answers from the collaborator.

ORGANIZATION				
6	**7**	**8**	**9**	**10**
Are the notes/receipts organized according to the unit's standard to simplify financial reporting?	Are the chapatex separated in a single bay and organized?	Are the containers separated by type and color in a tower format to facilitate checking?	Are plastics and cardboard segregated in a single bay to simplify disposal?	Are the pallets in good condition (without loose ends and/or broken)?
OK	OK	**NOK**	OK	OK
OK	OK	OK	**NOK**	OK
OK	OK	OK	OK	OK
OK	OK	OK	OK	OK
OK	OK	OK	OK	OK
OK	OK	OK	OK	**NOK**
OK	OK	OK	OK	**NOK**

Source: Authors, (2023).

The analysis of the critical evaluation by Evaluator 1 was important for implementing corrective actions to improve the organization of the truck, aiming to establish clear organization standards, ensure regular maintenance of organization, and train the employees involved in transport activities to follow established organization practices. The improvement in truck organization can result in greater efficiency in transport operations, reduced workload, and increased customer satisfaction, as we will see in the evaluation by Evaluator II;

Table 6 - Evaluator's Descriptive.

Month	O	Evaluator
Feb	100,00%	Evaluator II
Feb	100,00%	Evaluator II
Feb	100,00%	Evaluator II
Feb	100,00%	Evaluator II
Feb	100,00%	Evaluator II
Feb	100,00%	Evaluator II
Feb	80,00%	Evaluator II

Source: Authors, (2023).

Table 7 - Questions and answers from the collaborator.

ORGANIZATION				
6	**7**	**8**	**9**	**10**
Are the notes/receipts organized according to the unit's standard to simplify financial reporting?	Are the chapatex separated in a single bay and organized?	Are the containers separated by type and color in a tower format to facilitate checking?	Are plastics and cardboard segregated in a single bay to simplify disposal?	Are the pallets in good condition (without loose ends and/or broken)?
OK	OK	OK	OK	OK
OK	OK	OK	OK	OK
OK	OK	OK	OK	OK
OK	OK	OK	OK	OK
OK	OK	OK	OK	OK

ORGANIZATION				
6	**7**	**8**	**9**	**10**
Are the notes/receipts organized according to the unit's standard to simplify financial reporting?	Are the chapatex separated in a single bay and organized?	Are the containers separated by type and color in a tower format to facilitate checking?	Are plastics and cardboard segregated in a single bay to simplify disposal?	Are the pallets in good condition (without loose ends and/or broken)?
OK	OK	OK	OK	OK
OK	OK	OK	OK	OK

Source: Authors, (2023).

It is great news that the second evaluation has shown a 100% improvement in almost all areas assessed at Bramam Parintins in relation to the implementation of the second "S" of the 5S program. This indicates that the company has taken corrective measures and implemented actions to improve truck organization and achieve the established objectives.

IV.2.3 SEISO

Among the results obtained in the research, Bramam Parintins achieved 100% compliance in both assessments of the third "S" of the 5S, which is cleanliness. This indicates that the company is committed to maintaining a clean and organized environment in its operations. Maintaining a high level of cleanliness can bring various benefits to the company, such as:

Safe and Healthy Work Environment: Proper cleanliness contributes to the creation of a safe and healthy work environment, reducing the risks of accidents and occupational illnesses.

Operational Efficiency: A clean and organized environment facilitates the identification and access to materials, tools, and information necessary for operational activities, which can result in greater efficiency and productivity.

It is crucial for the company to continue monitoring and maintaining the established cleanliness standards, ensuring that employees are engaged in maintaining the third "S" of the 5S over time. Additionally, it is essential to identify and correct any deviations or opportunities for improvement in the cleanliness area to further enhance practices and results. With a clean and organized environment, the company can promote a safer, more efficient, and positive work environment for everyone involved.

IV.2.4 SEIKETSU

Achieving 100% compliance in both assessments of the fourth "S" of the 5S, which is standardization, demonstrates the company's commitment to maintaining and preserving the resources and assets used in its operations.

Standardization is an important aspect of the 5S program, aiming to promote responsibility and care for the company's resources, including machinery, equipment, tools, materials, and facilities.

IV.2.5 SHITSUKE

In the first assessment of the self-discipline sense of the 5S program at Bramam Parintins, it was identified that the team had low knowledge of the 5S principles and did not remember the main gaps identified. As a result, the utilization percentages remained in the range of 75%.

Self-discipline is one of the fundamental aspects of the 5S program, involving the commitment of employees to maintain established standards, follow procedures, and comply with the rules defined for organizing, cleaning, and preserving the work environment. It is a sense that requires awareness, responsibility, and constant monitoring by the entire team.

Table 8 - Evaluator's Descriptive.

Month	A	Evaluator
Jan	50,00%	Evaluator I
Jan	100,00%	Evaluator I
Jan	75,00%	Evaluator I
Jan	75,00%	Evaluator I
Jan	75,00%	Evaluator I
Jan	75,00%	Evaluator I
Jan	75,00%	Evaluator I

Source: Authors, (2023).

Table 9 - Questions and Responses Given to Employees.

SELF-DISCIPLINE			
14	**15**	**16**	**17**
Does the team know the meaning of the 5S?	Does the team know that there is a monthly audit routine? Do they remember the score from the last audit?	Does the team recall the main GAPs identified?	Does the team know that there is a recognition program for the best 5S Team? Can they explain how the program works and who were the winners last month?
NOK	OK	**NOK**	OK
OK	OK	OK	OK
OK	OK	**NOK**	OK
OK	OK	**NOK**	OK
OK	OK	**NOK**	OK
OK	OK	**NOK**	OK
OK	OK	**NOK**	OK

Source: Authors, (2023).

Over time, self-discipline was gradually incorporated into the organizational culture of the Bramam company, and employees began to understand the importance of following the established procedures of the 5S program to maintain a more organized, clean and efficient work environment.

The change in mindset and the adoption of a more disciplined stance in relation to the 5S program procedures brought positive results, contributing to the continuous improvement of internal processes and obtaining the expected benefits.

When we observe Table 9, we can see a significant improvement from one evaluator to another.

Table 10 - Evaluator's Description.

Month	A	Evaluator
Feb	100,00%	Evaluator II
Feb	100,00%	Evaluator II
Feb	100,00%	Evaluator II
Feb	100,00%	Evaluator II
Feb	100,00%	Evaluator II
Feb	100,00%	Evaluator II
Feb	100,00%	Evaluator II

Source: Authors, (2023).

Table 11 - Questions and Answers Given to Employees.

SELF-DISCIPLINE			
14	**15**	**16**	**17**
Does the team know the meaning of the 5S?	Does the team know that there is a monthly audit routine? Do they remember the score of the last audit?	Does the team remember the main GAPs identified?	Does the team know that there is a recognition program for the best 5S Team? Can they explain how the program works and who were the winners last month?
OK	OK	OK	OK
OK	OK	OK	OK
OK	OK	OK	OK
OK	OK	OK	OK
OK	OK	OK	OK
OK	OK	OK	OK
OK	OK	OK	OK

Source: Authors, (2023).

This is a positive indication that the corrective actions and awareness-raising implemented after the first assessment have had an effect and there has been significant improvement in the team's self-discipline regarding the principles of the 5S program. The 100% improvement in all requirements in the second assessment is a promising result and shows that the team is committed to implementing the 5S, understanding the importance of self-discipline in maintaining the established standards. It's important to recognize and value the efforts and results achieved by the team in this process. The 5S program applied to the trucks of the company Bramam Parintins also presented positive and negative points, which are detailed below:

IV.2.6 Positive Points

1. **Improved Vehicle Maintenance:** Implementing the 5S program in Bramam Parintins' trucks has led to improved vehicle maintenance. By standardizing cleaning, inspection, and preservation procedures for the trucks, it became possible to identify and fix issues more quickly, avoiding unscheduled stops and increasing vehicle availability for operations.

2. **Extended Vehicle Lifespan:** Adopting the 5S program also helped extend the trucks' lifespan. Through regular cleaning, identifying and fixing minor problems before they escalate, and standardizing preventive maintenance procedures, the vehicles' lifespan was prolonged. This reduced costs associated with corrective maintenance and premature part replacement.

IV.2.7 Negative Points

• **Resistance to Change:** As with any improvement program implementation, resistance to change from employees might have been a negative point in applying the 5S program to Bramam Parintins' trucks. Some employees might have resisted changes in maintenance procedures and routines, resulting in low adherence to the program and compromising its results.

• **Need for Training and Skill Development:** Properly applying the 5S program to the trucks requires training and skill development of the employees responsible for vehicle maintenance. Lack of adequate training might have been a negative point in the program's implementation, leading to failures in procedure application, error in problem identification, and inadequate vehicle preservation.

IV.3 FORKTLIFT

The implementation of the 5S program in the forklift sector has shown positive results in the first four S's, which are sense of use, organization, cleanliness, and preservation. However, the last S, which is the sense of self-discipline, has shown percentages below expectations, ranging from 50% to 75% in evaluations.

The first four S's have been well executed, with the team using the forklifts properly, keeping the area organized, clean, and preserved, following the 5S program guidelines. This has contributed to improved efficiency and productivity in the sector, avoiding accidents and damage to the forklifts, ensuring a safer and more efficient work environment.

However, the sense of self-discipline has presented challenges, with utilization percentages below expectations. This may indicate a need to reinforce the culture of discipline and responsibility among forklift operators, as well as the importance of following established procedures and guidelines for proper machine use.

Table 12 - 5S Description in the Forklift Sector.

MÊS	S	O	L	C	A
JAN	100,00%	100,00%	100,00%	100,00%	75,00%
JAN	100,00%	100,00%	100,00%	100,00%	75,00%
FEB	100,00%	100,00%	100,00%	100,00%	100,00%
FEB	100,00%	100,00%	100,00%	100,00%	100,00%
MAR	100,00%	100,00%	100,00%	100,00%	75,00%
MAR	100,00%	100,00%	100,00%	100,00%	50,00%

Source: Authors, (2023).

Table 13 - Questions Asked to Employees.

SELF-DISCIPLINE			
10	**11**	**12**	**13**
O empilhador sabe o significado dos 5S?	Does the forklift operator know that there is a monthly audit routine?	Does he remember the score of the last audit? Does the forklift operator remember the main GAPs identified?	Does the forklift operator know that there is a recognition program for the best 5S Team? Can they explain how the program works and who were the winners last month?
OK	OK	**NOK**	OK
OK	OK	**NOK**	OK
OK	OK	OK	OK
OK	OK	OK	OK
OK	OK	OK	**NOK**
OK	OK	**NOK**	**NOK**

Source: Authors, (2023).

It's crucial to identify the causes of this low self-discipline, such as possible gaps in training, lack of operator awareness about the importance of following procedures, or inadequate supervision. Based on this analysis, corrective actions can be taken, such as reinforcing training, establishing clear procedures, creating performance indicators, and strengthening supervision to improve self-discipline in the forklift sector.

The implementation of the 5S program is an ongoing process, and it is vital for the company to maintain constant monitoring of progress, identifying areas for improvement, and acting proactively to address identified weaknesses. With awareness and team engagement, it is possible to overcome the challenges related to self-discipline and achieve positive results in all aspects of the program, contributing to the continuous improvement of the forklift sector and, consequently, the overall performance of the company.

IV.4 DATA ON PROGRESS

IV.4.1 Warehouse

Periodic evaluations were conducted to measure the progress of the 5S program in the warehouse sector of Bramam company. The results obtained were analyzed and showed positive evolution over the months. In January, the program utilization rate was 49.49%. In February, there was an improvement, with the rate rising to 55.43%. In March, another increase was recorded, reaching a rate of 59.59%. In April, there was a significant increase to 70.92%. In May, there was a continuous increase to 76.99%. As of this June, the rate has increased to 80.33%.

Figure 2 - Descriptive of the 5S in the Warehouse.
Source: Authors, (2023).

Figure 3: Image of the warehouse office before the application of the 5S program.
Source: Authors, (2023).

Figure 4: Images of the warehouse office after the application of the 5S program.
Source: Authors, (2023).

These data highlight the effectiveness of Bramam's improvement project based on the 5S program. Through the implementation of the program's principles, the warehouse sector employees are fostering a cultural shift, adopting habits of use, organization, cleanliness, preservation, and self-discipline in the workplace. These positive outcomes are reflected in a gradual increase in the program's utilization rate, indicating consistent evolution over time.

Furthermore, the development of self-discipline among the employees is promoting greater responsibility and commitment in executing procedures, as well as in maintaining the standards set by the 5S program. This is creating a culture of continuous improvement, where employees are constantly seeking to identify opportunities for enhancement and implement corrective actions.

In summary, the 5S project at Bramam aims to enhance efficiency and organization in the warehouse sector through the implementation of the 5S program principles. The methodology involved raising awareness, training, and sequential implementation of the program's five principles: sense of use, sense of organization, sense of cleanliness, sense of preservation, and sense of self-discipline. The results obtained demonstrate a positive evolution in the program's utilization rates over the months, reflecting benefits for the company in terms of efficiency and quality.

Figure 5: Material storage before the application of the 5S program.
Source: Authors, (2023).

Figure 6: Material storage after the application of the 5S program.
Source: Mendonça (2023).

IV.4.2 Trucks

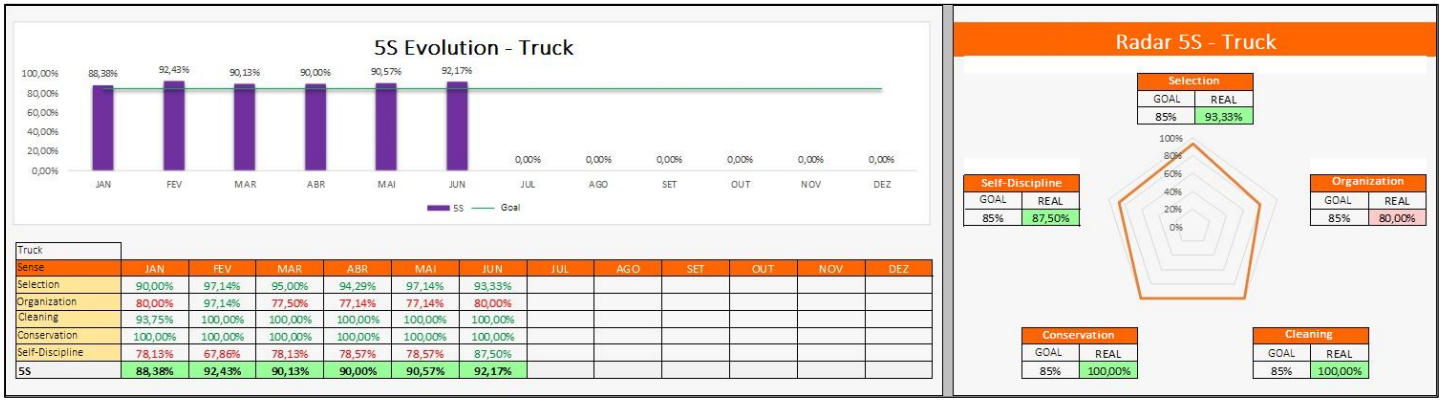
The results of the evolution of the 5S program sensibilities in Bramam's truck sector showed variation over the months. In January, the utilization rate of the sensibilities was 88.38%, indicating good adherence to the program. In February, there was a significant improvement, with the rate rising to 92.43%, demonstrating positive progress in the practices of use, organization, cleanliness, preservation, and self-discipline in the sector. However, in March, there was a decline, with the rate falling to 90.13%, highlighting the need for corrective actions to maintain consistent evolution over time. In April, the rate was stable at 90.00%. In May, the indicator reached 90.57%. As of this June, it is showing an increased indicator of 92.17%, resulting in efficiency and quality in transport operations.

This variation in the utilization rates of the 5S program sensibilities in the truck sector of Bramam underscores the importance of regular and continuous monitoring of the project. It's essential to identify the causes of the decline in March and implement corrective actions to return to the path of continuous improvement. There might have been deviations in the practices of use, organization, cleanliness, preservation, and self-discipline, or new challenges that impacted the sector's performance.

Given this variation in results, a detailed analysis of the processes and procedures in the truck sector is necessary, identifying potential areas for improvement. It's also important to promote awareness and training activities for the employees, emphasizing the importance of the 5S program principles and encouraging their adoption as a work routine.

Moreover, maintaining clear and transparent communication about the objectives and results of the 5S program in the truck sector is crucial. It's important for employees to

understand the program's significance for the sector's efficient functioning and for achieving the company's overall objectives. Sharing the results obtained, both positive and challenging, can motivate employees' commitment and engagement in seeking improvements.



Truck												
Sense	JAN	FEV	MAR	ABR	MAI	JUN	JUL	AGO	SET	OUT	NOV	DEZ
Selection	90,00%	97,14%	95,00%	94,29%	97,14%	93,33%						
Organization	80,00%	97,14%	77,50%	77,14%	77,14%	80,00%						
Cleaning	93,75%	100,00%	100,00%	100,00%	100,00%	100,00%						
Conservation	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%						
Self-Discipline	78,13%	67,86%	78,13%	78,57%	78,57%	87,50%						
5S	88,38%	92,43%	90,13%	90,00%	90,57%	92,17%						

Figure 7- 5S Description on the Truck.
Source: Authors, (2023).

Figure 8: Image of trucks before the application of the 5S program.
Source: Authors, (2023).

Figure 9: Image of trucks after the application of the 5S program.
Source: Authors, (2023).

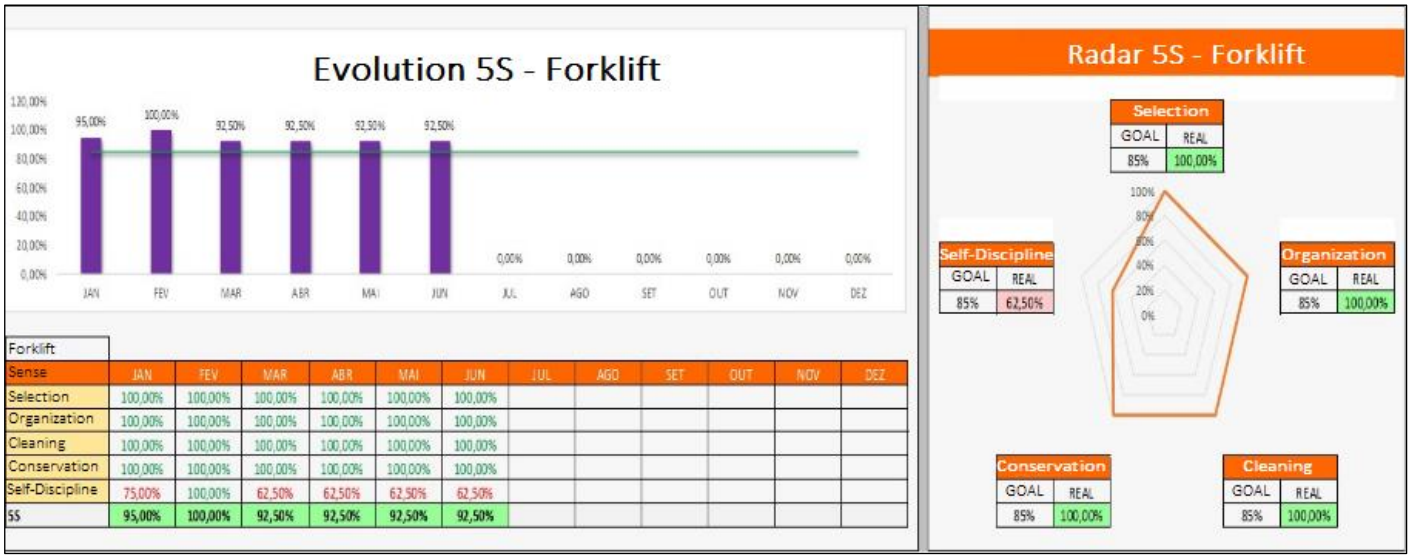
IV.4.3 Forklift

The results of the evolution of the 5S program sensibilities in Bramam's forklift sector showed variations in the utilization rates over the months. In January, the utilization rate was 95%, indicating good adherence to the program and strong performance in use, organization, cleanliness, preservation, and self-discipline in the sector. In February, there was a significant improvement, with the rate reaching 100%, indicating excellent performance and consistent application of the 5S program principles. However, in March, there was a decline in utilization, with the rate falling to 92.50%, highlighting the need to identify and correct possible deviations in program practices. The rate remained at 92.50% in April, May, and June.

Given these variations in results, a detailed analysis of the processes and procedures in the forklift sector is necessary, identifying possible causes of the decline in March. There may have been lapses in use, organization, cleanliness, preservation, or self-discipline, or new challenges that impacted the sector's performance.

One strategy to correct possible deviations and promote continuous improvement is to reinforce employee training, with specific focus on the 5S program and its practices. Employees must understand the benefits of the program and how its practices directly impact the efficiency and productivity of the sector.

Another action that can be taken is establishing routines for internal audits to check the application of the 5S program principles in the forklift sector. These audits can be conducted periodically, involving employees and identifying opportunities for improvement. It's crucial that the audits are conducted impartially and that the results are shared transparently with the employees, so that everyone can contribute to identifying solutions.



Forklift												
Sense	JAN	FEV	MAR	ABR	MAI	JUN	JUL	AGO	SET	OUT	NOV	DEZ
Selection	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%						
Organization	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%						
Cleaning	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%						
Conservation	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%						
Self-Discipline	75,00%	100,00%	62,50%	62,50%	62,50%	62,50%						
5S	**95,00%**	**100,00%**	**92,50%**	**92,50%**	**92,50%**	**92,50%**						

Figure 10 - Description of 5S on the Forklift.
Source: Authors, (2023).

Figure 11: Images of the forklift after the application of the 5S program.
Source: Authors, (2023).

V. CONCLUSIONS

The five principles of the 5S are fundamental for promoting organization, cleanliness, discipline, and continuous improvement in a work environment. The Sense of Use concerns identifying and removing unnecessary items from the workplace. The Sense of Order involves defining appropriate places for each item to facilitate access and efficient use of resources. The Sense of Cleanliness encompasses maintaining a clean and safe environment, contributing to accident prevention and health promotion. The Sense of Health/Neatness refers to personal hygiene, appropriate clothing, and the health of employees. Finally, the Sense of Self-Discipline is related to maintaining established standards and the constant pursuit of improvement.

The implementation of the 5S in companies can bring various benefits, such as improving the work environment, increasing efficiency and productivity, reducing costs, stimulating a quality culture, and promoting a sense of belonging and responsibility among employees. It's a simple yet effective approach that can be applied in organizations of any size or sector, contributing to the continuous improvement of processes and results.

Based on the analyzed data, it can be concluded that Bramam Parintins has made significant progress in implementing the 5S program in its work environment. The initial assessment showed opportunities for improvement, particularly in self-discipline, where the team achieved a utilization rate of 75%. However, the second assessment revealed an impressive evolution of 100% in all requirements, demonstrating the team's commitment to adopting the program's principles.

The company's effort to promote organization, cleanliness, preservation, and self-discipline in the workplace is noteworthy, aiming to improve efficiency, productivity, and the quality of processes. The positive points identified in the evaluations show that the company is on the right track to achieve operational excellence through the implementation of the 5S.

It is important to emphasize the need to maintain constant monitoring, provide training, and reinforce the culture of continuous improvement to ensure the sustainability of the 5S program over time. It is an ongoing process that requires the engagement of the entire team, from top management to employees at all hierarchical levels.

Based on the obtained results and the positive evolution, Bramam Parintins is on the right path to achieving a more organized, clean, preserved, and disciplined work environment, which can contribute to process optimization, employee satisfaction, and the improvement of the quality of products and services offered.

In summary, the implementation of the 5S program at Bramam Parintins has shown positive results, with advances in self-discipline and the adoption of the program's principles. It is a continuous process that requires monitoring and engagement from the entire team, aiming for continuous improvement and the pursuit of operational excellence.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Roberta Pontes da Costa, Thiago Mendonça de Souza, Bruna Lorrayne Vasconcelos Barros, Vanessa Coelho da Silva, Emanuel Kedson da Silva Freitas and Aderli Vasconcelos Simões.
Methodology: Roberta Pontes da Costa, Thiago Mendonça de Souza, Bruna Lorrayne Vasconcelos Barros, Vanessa Coelho da Silva, Emanuel Kedson da Silva Freitas and Aderli Vasconcelos Simões.
Investigation: Roberta Pontes da Costa, Thiago Mendonça de Souza, Bruna Lorrayne Vasconcelos Barros, Vanessa Coelho da Silva, Emanuel Kedson da Silva Freitas and Aderli Vasconcelos Simões.
Discussion of results: Roberta Pontes da Costa, Thiago Mendonça de Souza, Bruna Lorrayne Vasconcelos Barros, Vanessa Coelho da Silva, Emanuel Kedson da Silva Freitas and Aderli Vasconcelos Simões.
Writing – Original Draft: Roberta Pontes da Costa, Thiago Mendonça de Souza, Bruna Lorrayne Vasconcelos Barros, Vanessa Coelho da Silva, Emanuel Kedson da Silva Freitas and Aderli Vasconcelos Simões.
Writing – Review and Editing: Vanessa Coelho da Silva, Emanuel Kedson da Silva Freitas and Aderli Vasconcelos Simões.
Resources: Roberta Pontes da Costa, Thiago Mendonça de Souza and Bruna Lorrayne Vasconcelos Barros.
Supervision: Vanessa Coelho da Silva, Emanuel Kedson da Silva Freitas and Aderli Vasconcelos Simões.
Approval of the final text: Roberta Pontes da Costa, Thiago Mendonça de Souza, Bruna Lorrayne Vasconcelos Barros, Vanessa Coelho da Silva, Emanuel Kedson da Silva Freitas and Aderli Vasconcelos Simões.

VII. REFERENCES

[1] LINO, ANDRÉ DA SILVA. Gestão da manutenção. 1994.

[2] MARSHALL, Island Junior (org). Quality Management. Rio de Janeiro: FGV Publisher, 2003.

[3] PALADINI, Edson Pacheco. Quality Management: Theory and Practice, 2nd Ed. São Paulo: Atlas, 2004.

[4] MAXIMIANO, Antonio Cesar Amaru. Introduction to Administration, 4th Ed. São Paulo: Atlas, 1995.

[5] Werkema, M. C. (2006). Lean Seis Sigma Introdugma: Estratégia gerencial manufacturing. Rio de Janeiro: Wekema.

[6] GANDRA, Marco Aurélio, et al. 5S Program in the Factory. CEFET-MG. Belo Horizonte - MG, 2006. Available at: [http://www.leadempresarial.com.br/site_lead/imagens_arquivos/academica/Programa%205S%20na%20Fabrica.pdf].

[7] BENEMANN, Raphael Roveda. Considerations on the Use of the 5S Program. Available at: [http://www.cyber7.com.br/index.php/artigos/18-consideracoes-sobre-a-utilizacao-do-programa-5s]. Accessed in: Oct. 2012.

[8] BREKAILO, Fernanda; MUGNAINE, Michele; PEREIRA, Alan W; KUGLER, Bruno Hermannus; BRODAY, Evandro E. Theoretical Implementation of the 5S Program in the material transformation center of UTFPR. Salvador-BA. Available at: [https://abepro.org.br/biblioteca/enegep2013_TN_STO_178_019_21900.pdf].

[9] CANTO, Liliam Caroline Cardoso, et al. Implementation of the 5S System in the Storage Sector of a Small Company in Southern Santa Catarina. In: XXVI National Meeting of Production Engineering, 2006.

[10] ZANINI, Edinilson. The Importance of 5S for Companies. Available at: [http://www.edigital.com.br/index.php?option=com_content&view=article&id=113:a-importancia-do-5s-para-as-empresas&catid=31:gestao&Itemid=46]. Accessed in: Oct. 2012.

[11] ISOFLEX, 2023. Available at: [https://isoflex.com.br/wp-content/uploads/2019/10/5s.jpg].

[12] Stank, TP, Daugherty, PJ e Ellinger, AE (1999). Integração marketing/logística e desempenho da empresa. O Jornal Internacional de Gestão Logística , 10 (1), 11-24.

[13] Novaes, A. G. (1989). Sistemas logísticos: transporte, armazenagem e distribuição física de produtos.

[14] Figueiredo, K., & Arkader, R. (1998). Da distribuição física ao supply chain management: o pensamento, o ensino e as necessidades de capacitação em logística. Revista Tecnologística, 33, 16.

[15] Christopher, M. e Peck, H. (1997). Gestão da logística nos mercados de moda. O Jornal Internacional de Gestão Logística , 8 (2), 63-74.

[16] PRODANOV, C.C.; FREITAS, E.C. Scientific Work Methodology: Methods and Techniques of Research and Academic Work. 2nd ed. Novo Hamburgo: Feevale, 2013.

[17] GERHARDT, T.E.; SILVEIRA, D.T. Research Methods. Porto Alegre: UFRGS Publisher, 2009.

Journal of Engineering and Technology for Industrial Applications

ISSN ONLINE: 2447-0228

ITEGAM-JETIA

Manaus, v.9 n.44, p. 49-53. Nov/Dec, 2023

DOI: https://doi.org/10.5935/jetia.v9i44.1011

RESEARCH ARTICLE OPEN ACCESS

DEVELOPMENT OF AN EXTERNAL PUMP FOR OIL TRANSFER FOR MAINTENANCE OF TRUCK LIFTING PLATFORMS

Anderson Bittencourt Gimack*[1], Antônio Clisma Dantas de Oliveira[2], Douglas Pereira de Souza[3] and Marcus Renato Pinheiro Mattos[4]

[1, 2, 3, 4] Department of mechanical engineering, Centro Universitário do Norte – UNINORTE, Manaus, Amazonas, Brazil.

[1] http://orcid.org/0009-0005-3699-3707, [2] http://orcid.org/0009-0005-4941-8189, [3] http://orcid.org/0009-0005-2507-7404, [4] http://orcid.org/0009-0005-3323-4844

Email: *andersongimack@gmail.com, antonio.clisma@hotmail.com, douglas.dps97@gmail.com, marcusrenat.eng@outlook.com

ARTICLE INFO

Article History
Received: November 17th, 2023
Revised: December 05th, 2023
Accepted: December 07th, 2023
Published: December 30th, 2023

Keywords:
Oil Pump,
Lifting Platforms,
Efficient Maintenance.

ABSTRACT

This work focuses on adapting an external oil transfer pump to improve the maintenance efficiency of truck lift platforms. The motivation behind this research arises from the need identified in the maintenance operations of these equipment, often faced with challenges in transferring and handling oil to the truck platform lifting system, resulting in unnecessary product losses and prolonged maintenance time. The main objective of this project is to adapt an external oil pump, which optimizes the maintenance process of truck lift platforms, saving time and reducing oil waste. To achieve this objective, the research explores different pump technologies available on the market, considering the advantages, disadvantages and costs involved. The methodology involves a study of the operation of lifting platforms and the difficulties faced in their maintenance. Finally, an external transfer system was designed and tested with the aim of evaluating its efficiency and functionality. It is believed that this work will not only optimize the maintenance process of truck lift platforms, but will also contribute to reducing oil waste, generating significant benefits in terms of saving resources and time in the daily maintenance operations of this equipment.

I. INTRODUCTION

The freight transportation industry has grown over the years, increasing the need for maintenance of truck lift platforms. Oil transfer during maintenance is time-consuming, expensive, prone to error and waste. The objective of this work is to adapt an external oil transfer pump capable of optimizing the maintenance process of truck lifting platforms.

The aim of the new pump is to reduce oil transfer time and minimize waste during maintenance of truck lift platforms. The central question of the research is how to select and adapt an external pump to the platform system capable of reducing oil waste and maintenance time. To answer this question, the research will include a literature review, the selection and adaptation of a pump available for use, followed by comparative testing of results under different operating conditions.

The main objective of this work is to adapt an oil pump, external to the platform's organic system, capable of optimizing the maintenance of truck lifting platforms. This proposal will be achieved by saving time when carrying out maintenance and minimizing oil waste during the process [1]. Therefore, the result is expected to be a significant improvement in the efficiency of the maintenance process.

The central research question is how to adapt an oil pump to improve efficiency in truck lift platform maintenance, involving an analysis of current processes to identify areas for improvement. The research seeks to contribute to mechanical engineering by offering low-cost equipment that has applicability in the current context and similar ones, increasing its relevance.

The proposal fits within mechanical engineering in the hydraulic systems discipline. Although there are several studies carried out to improve the efficiency and reliability of these systems, which is crucial to ensure the safety and effectiveness of

lifting operations [2]. The present study considers the difficulty of accessing the lifting system reservoir, which generates oil waste.

Maintenance of lifting platforms is a critical aspect of ensuring their safe and efficient operation. Failure to perform adequate maintenance can lead to unexpected and potentially dangerous downtime. The use of a suitable oil transfer pump can significantly facilitate maintenance operations, allowing a quick and clean fluid change [3].

Adapting an oil transfer pump to maintain truck lift platforms requires research into pumping systems available on the market. There are several types of pumps with specific advantages and disadvantages, the choice depends on the viscosity of the fluid, the operating conditions and the costs involved.

In short, choosing an oil transfer pump involves a series of important technical considerations. The literature review suggests that the appropriate choice of pump type, a robust and durable design, and energy efficiency are critical aspects to be considered.

Manufacturers seek improvements in pump efficiency, with many focusing on aspects such as compact form factor, ease of use, and ability to handle different types of oil [4]. Furthermore, technological advances have allowed the development of pumps with greater precision in controlling oil flow and pressure [5].

In the case of the present work, the issue related to pressure and oil characteristics are not a priority, as the objective is to build a simple oil transfer system to the truck's lifting system reservoir, bypassing the difficult access between the truck pump and lifting system and the system reservoir.

From the above, the adaptation of an external oil transfer pump for the maintenance of truck lifting platforms requires the application of hydraulic systems and the analysis of the operational needs and difficulties identified in the daily maintenance operation. The use of simple techniques can contribute to the creation of an efficient, reliable solution with an adequate cost-benefit ratio.

The general objective of the work is to adapt a simple and effective oil pump, capable of optimizing the maintenance process of truck lifting platforms. This aims to not only save time, but also minimize oil waste during operation.

II. METHODOLOGY

The methodology was carried out in three stages, starting with a broad literature review to identify best practices and existing technologies related to the development and operation of oil transfer pumps. This review will help identify which features are essential for an effective and efficient pump, as well as any potential gaps in current technology [6].

Then secondary research will be conducted to collect information on the types of pumps that are commonly used in the industry. This will include a study of the advantages and disadvantages of the types of pumps available on the market. Sources of this data may include manufacturer user manuals, technical reports, and published studies [7]. The table below shows a comparison between five types of pumps available on the market.

Table 1: Types and Characteristics and advantages and disadvantages of pumps.

PUMP TYPE	DESCRIPTION	ADVANTAGE	DISADVANTAGES	COST
Hydraulic Gear Pump	Gear pumps are used in the hydraulic systems of smaller truck lift platforms. They are compact, efficient and provide a continuous flow of hydraulic fluid.	Simplicity of construction and low cost. Good efficiency in medium pressure systems. Quiet operation compared to some other pumps. Suitable for low to medium pressure and flow applications.	Less efficient at high pressures. Faster gear wear at high speeds. Tendency to generate pulsations in the flow.	Low.
Axial Piston Hydraulic Pump	Axial piston pumps are often employed in lift platform systems for larger and heavier trucks. They are capable of generating higher pressures and are known for their efficiency and ability to deliver high power.	High efficiency over a wide range of pressures. High speed operation capability. Good dynamic response, suitable for systems requiring precise control.	Greater construction complexity. More demanding maintenance.	High.
Radial Piston Hydraulic Pump	Radial piston pumps are similar to axial piston pumps in terms of application, but have a slightly different design. They are used in lifting systems that require very high pressures and are known for their quick response capabilities.	High efficiency over a wide range of pressures. Good dynamic response. High speed operation capability.	Construction complexity. Requires more careful maintenance.	Moderate.
External Gear Hydraulic Pump	External gear pumps are suitable for medium-duty applications and offer a combination of performance and durability.	Simplicity of construction. Acceptable efficiency in medium pressure systems. Relatively silent operation.	Less efficient at high pressures. Tendency to generate pulsations in the flow.	Moderate.
Hydraulic Vane Pump	Vane pumps are compact and are often used in smaller truck lift systems and general lifting equipment.	Silent operation. Simplicity of construction. Suitable for low to medium pressure and flow applications.	Lower efficiency compared to some other pumps in high pressure systems. Vane wear requires periodic maintenance.	Moderate.

Source: Adapted from [8].

After collecting the secondary data, a tertiary survey will be carried out to collect information directly from the maintenance operators of these lifting platforms. This may involve interviews or questionnaires with mechanics, platform operators and maintenance managers. These individuals will be selected through a stratified random sample to ensure a wide range of experiences and perspectives are captured [9].

When considering that the exact quantification of problems faced by truck lift platform users can vary widely depending on context, platform type, location of use and other factors, data collection requires specific information, directing the response to an approximate representation of the severity of each issue based on a relative importance scale.

Therefore, specific information will be based on ten aspects: frequent maintenance and repairs; hydraulic leaks; excessive noise; complex maintenance; lack of adequate training; maintenance cost; difficulties in replacing oil, wastage of oil, and safety. The result of the simulation will provide relevant information about the percentage of participation of each aspect involved in equipment maintenance.

Finally, the results of the analysis were used in the development of the oil transfer system, which will be subjected to rigorous testing to ensure it meets the requirements identified in the research phase. The figure below shows the oil transfer scheme.

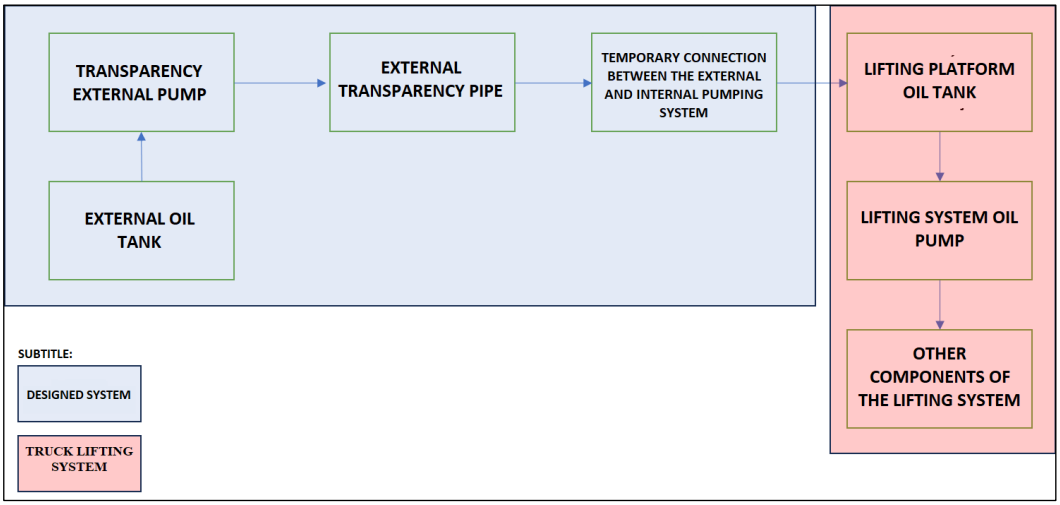


Figure 1: Schematic of the designed pumping system and its interconnection with the truck lifting system.
Source: Authors, (2023).

III. RESULTS AND DISCUSSION

The results of the development of an oil transfer system, with the aid of an external pump, in the maintenance operation of truck lifting platforms were very promising. The pump was successfully adapted and allowed the maintenance process to be optimized, making it more efficient, safe, faster and less expensive.

Research on the pump model to be used in the oil transmission process from the external reservoir to the lifting system reservoir indicated the Hydraulic Gear Pump as the most advantageous, due to its simplicity, operation at low flow pressure, ease of operation, low noise and, especially, low acquisition cost.

From the collection and analysis of data regarding the current maintenance process of lifting platforms, it was possible to conclude that the current process is time-consuming, potentially dangerous and expensive, considering the waste of oil generated by the manual process of insertion into the hydraulic system reservoir of the lifting platform. elevation. The figure below shows the results of the survey carried out with maintenance operators:

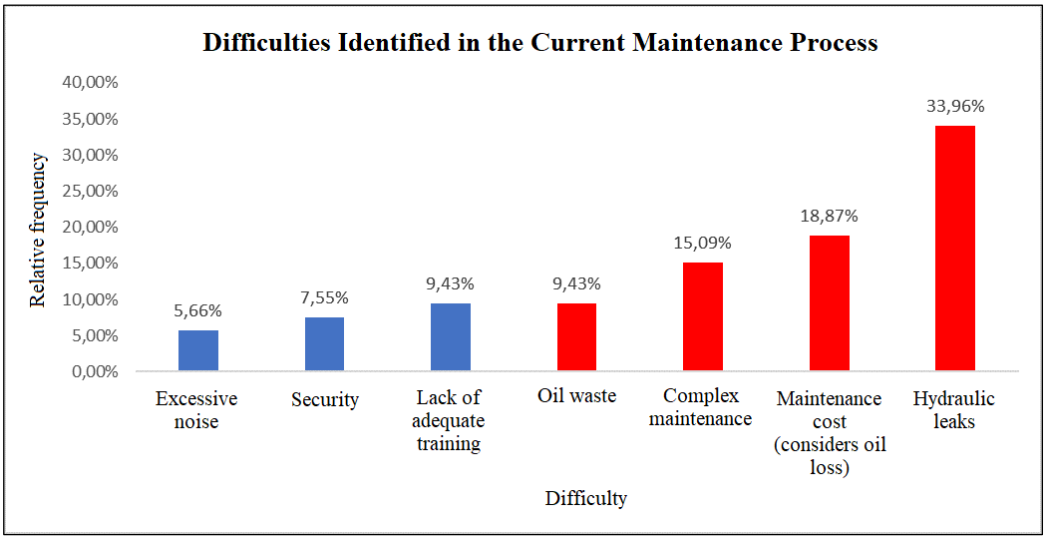


Figure 2: Difficulties identified in the current maintenance process.
Source: Authors, (2023).

Based on this information, the design of the oil transmission system for the lifting system showed the need to introduce an external pump with a focus on reducing oil waste and the complexity of the maintenance process. The chosen pump, due to its ability to pressurize, medium pressure, the oil transfer system, significantly reduced the time required for maintenance from forty minutes to fifteen minutes per truck.

As can be seen in the photo album attached to this work, in preliminary conclusion, the results indicate that the use of the pump in the transmission process from the external to the internal reservoir to the platform lifting system significantly improved the maintenance process of lifting platforms of trucks. However, as shown in the graph in figure 2, an increase in the training of maintenance personnel is necessary.

The photo album attached to the work details the test phases, where it was possible to observe that the new pump is capable of transferring oil in a time two and a half times longer than the manual transfer process previously used. This represents a significant reduction in the time required to maintain trucks. Furthermore, the new pump proved to be robust and resistant, with little or no need for maintenance throughout the test period.

Another important aspect observed during the tests was the fact that the new pump does not allow oil to spill during the transfer process from the primary reservoir to the truck platform lifting system reservoir, this promotes a safer and more efficient working environment. clean.

Regarding the cost-benefit regarding the installation of the pump, the results were equally positive, considering the cost of implementing the system and the savings related to reducing oil waste in the transfer operation. The introduction of the additional pump provided a cost-benefit ratio $\frac{C}{B} = \frac{Benefício\ Líquido}{Custo\ total} = \frac{15000}{500} = \frac{30}{1}$), which means for an investment of 500 reais it provided savings, resulting from the reduction of oil waste, of 15,000 thousand reais.

The results obtained after implementing the external pump for oil transfer indicated a significant improvement in the efficiency and safety of the process, resulting from the reduction in maintenance time and the complexity of the operation.

The development of the oil transfer process for the truck platform lifting system is in line with the literature review on the subject. According to [10], efficiency in preventive maintenance is crucial to ensuring operational reliability and safety in maintenance operations. In the specific case of truck lifting platforms, maintenance procedures involve frequent oil replacement, a process that can be time-consuming, complex and costly if carried out using manual processes.

The pump used in this project incorporated features that improved both the safety and efficiency of the process. According to [11], the innovative use of technology can substantially improve preventive maintenance procedures. In this context, the use of an external pump represents a significant contribution to the field. The implications of these results are important from both a practical and theoretical point of view.

In practice, the incorporation of an external pump in daily operations resulted in significant savings in time and human resources, in addition to reducing potential risks associated with inadequate oil handling. Theoretically, these results reinforce existing literature that emphasizes the importance of innovation in preventive maintenance [10] and [12].

The reviewed literature and preliminary research into the development of an external system, with the introduction of a pump, demonstrated the need for innovations in this specific field, in line with the studies carried out by [13] showing that the time spent maintaining lifting platforms is one of the biggest challenges faced by companies in the sector. In this sense, the results obtained in this work confirm the hypothesis proposed by the authors, indicating that the use of an external pump can be a viable and efficient solution to this problem.

Another relevant point concerns sustainability. According to [14] and [15], the need for more sustainable practices in industry and society is urgent. In this context, the work presented reduced oil waste compared to traditional methods, thus contributing to a lower environmental impact.

According to the results obtained, it was clear that the development of this work provided a significant improvement in the maintenance of Truck Lifting Platforms. This aligns with existing literature on the topic, which suggests that the operational efficiency of this equipment is highly dependent on regular and adequate maintenance [16] and [17].

From all the above, the importance of the results presented in the present work lies in their application in maintenance practice, considering the high costs associated with mechanical failures, idle time during maintenance, oil waste and the complexity of the oil transfer operation. oil indicate that any improvements in these areas could lead to significant savings.

Thus, the development of a process for transferring oil from an external reservoir to the internal reservoir of the platform lifting system, using a low-cost pump, presents valuable potential to improve the general operational performance and profitability of companies that carry out maintenance services, as well as those that use trucks with lifting platforms.

IV. CONCLUSION

Throughout the research it was possible to employ an external pump that allows the transfer of oil to the internal lifting system of the truck platform during the maintenance operation, which played a crucial role in efficiency, simplification of the operation, safety of the maintenance team and reduction of oil waste.

The results obtained show that the external pump significantly increases the speed and accuracy of oil transfer, reducing the time required for maintenance, minimizing the risk of human errors and oil waste. Furthermore, the pump also allows the reduction of environmental impacts resulting from oil spills.

In practical terms, these advantages imply lower operating costs, greater safety for workers and an adequate cost-benefit ratio. It is also important to note that the external pump is part of an external system that is easily adaptable to different types of lifting platforms, making it a versatile solution for different situations.

Therefore, the results of this work imply important advances, both from a technical and economic point of view. The use of the external pump represents an important step towards improving maintenance operations on truck lifting platforms, contributing to making this activity safer, simpler and more efficient.

The external pump proved capable of transferring the oil in two and a half times less time than the manual method previously used. This means considerable savings in time and human resources. Furthermore, the pump showed a very low failure rate during tests, which suggests greater durability and reliability for the system.

It is important to highlight that the improvement in efficiency did not compromise the safety of operators, on the contrary, by reducing the complexity of the operation, it added

safety for maintenance personnel. Therefore, it can be said that the introduction of the external pump represents a significant advance in the area of lifting platform maintenance.

In short, the introduction of this pump has important implications not only for companies that operate lifting platforms, but also for maintenance service providers. Savings in time and human resources can be used in other areas of the company, increasing its competitiveness in the market [18]. Furthermore, the lower complexity in the maintenance operation provides agility and simplicity to the service, potentially mitigating workplace accidents, a benefit that extends to workers and society in general [19].

However, aspects were observed that could promote the improvement of the developed system, especially related to the external reservoir and the addition of a device for measuring the level of the lifting system reservoir, when transferring the oil.

V. AUTHORS' CONTRIBUTION

Conceptualization: Anderson Bittencourt Gimack, Antônio Clisma Dantas de Oliveira and Douglas Pereira de Souza.
Methodology: Anderson Bittencourt Gimack, Antônio Clisma Dantas de Oliveira and Douglas Pereira de Souza.
Investigation: Anderson Bittencourt Gimack, Antônio Clisma Dantas de Oliveira and Douglas Pereira de Souza.
Discussion of results: Anderson Bittencourt Gimack, Antônio Clisma Dantas de Oliveira and Douglas Pereira de Souza.
Writing –Original Draft: Anderson Bittencourt Gimack, Antônio Clisma Dantas de Oliveira, Douglas Pereira de Souza and Marcus Renato Pinheiro Mattos.
Writing –Review and Editing: Marcus Renato Pinheiro Mattos.
Resources: Anderson Bittencourt Gimack, Antônio Clisma Dantas de Oliveira and Douglas Pereira de Souza.
Supervision: Marcus Renato Pinheiro Mattos.
Approval of the final text: Anderson Bittencourt Gimack, Antônio Clisma Dantas de Oliveira, Douglas Pereira de Souza and Marcus Renato Pinheiro Mattos.

VI. REFERENCES

[1] XIONG, Y. Hydraulic Fluid Technology: Advanced Performance Hydraulic Fluids and Their Applications. Hoboken, NJ, 2018.

[2] LIU, H.; LI, W.; GAO, F. Research on the hydraulic system of the truck-mounted crane based on energy-saving control technology. Procedia Engineering, v. 129, p. 146-152, 2015.

[3] XU, B.; WANG, J. Diagnóstico de falhas e manutenção de sistemas de elevação hidráulica de caminhões pesados baseado em manutenção centrada em confiabilidade. Journal of Industrial Engineering and Management Innovation, v. 61, n. 3, p. 448-457, 2014.

[4] SMITH, J. Design considerations in the development of efficient oil transfer pump for truck lifting platforms maintenance. Journal of Industrial Design and Manufacturing, v. 10, n. 1, p. 34-40, 2015.

[5] JOHNSON, T.; TURNER, P. Technological advances in oil transfer pumps for service trucks. Journal of Transport Technology, v. 8, n. 1, p. 67-73, 2020.

[6] TIDD, J.; BESSANT, J.R. Managing innovation: Integrating technological, market and organizational change. John Wiley & Sons, 2018.

[7] CRESWELL, J.W.; CRESWELL, J.D. Research design: Qualitative, quantitative and mixed methods approaches. Sage Publications, 2017.

[8] SUNDARRAJ, S. Características e Aplicações de Bombas. CRC Press, 2016.

[9] BRYMAN, A.; BELL, E. Business research methods. Oxford University Press, 2015.

[10] ZENG, S. X.; SWANSON, D. Medição de Desempenho da Manutenção Preditiva: Um Sistema de Benchmarking Dedicado. International Journal of Production Research, v. 48, n. 23, p. 7045-7062, 2010.

[11] MOBLEY, R. K. An Introduction to Predictive Maintenance. Elsevier, 2002.

[12] CORREA, Rafael Santos; DO NASCIMENTO, José Fernando Silva; NEVES, Fernando Frachone. Práticas de inspeção e manutenção preventiva em sistemas fotovoltaicos. Ciência & Tecnologia, v. 15, n. 1, p. e1514-e1514, 2023.

[13] JOHNSON, A.; LEE, B.; KIM, Y. O Impacto do Tempo de Manutenção na Produtividade da Indústria. International Journal of Industrial Engineering, v. 25, n. 1, p. 15-30, 2018.

[14] WILLIAMS, R.; THOMAS, S.; GREEN, J. Sustentabilidade na indústria: uma necessidade urgente. Journal of Sustainable Development, v. 15, n. 4, p. 67-80, 2020.

[15] BRITO, WILDERLAN BARRETO. Gestão de resíduos sólidos e sustentabilidade: uma revisão bibliográfica da prática na maior favela do Brasil. 2023. Dissertação de Mestrado.

[16] SMITH, J.; JONES, M. Manutenção de Plataformas Elevatórias: Desafios e Soluções. Journal of Engineering, v. 10, n. 2, p. 35-45, 2015.

[17] NEPOMUCENO, Lauro Xavier. Técnicas de manutenção preditiva - Vol. 1. Editora Blucher, 2014.

[18] BROWN, A.; SMITH, B.; JONES, C. Efficiency in the maintenance of lifting platforms: a case study. Journal of Industrial Engineering, v. 45, n. 2, p. 123-135, 2017.

[19] WILLIAMS, R. The impact of workplace accidents on society: an analysis. Social Sciences Review Journal, v. 35, n. 1, p. 10-20, 2019.

Journal of Engineering and Technology for Industrial Applications

ISSN ONLINE: 2447-0228

ITEGAM-JETIA

Manaus, v.9 n.44, p. 54-62. Nov/Dec, 2023

DOI: https://doi.org/10.5935/jetia.v9i44.1012

RESEARCH ARTICLE OPEN ACCESS

PROCESS MAPPING: A CASE STUDY IN THE CONTRACT SECTOR OF THE PUBLIC DEFENDER'S OFFICE IN THE STATE OF AMAZONAS

Rafaela Barbosa Nascimento[1], Elton Pereira Teixeira[2], Orlem Pinheiro de Lima*[3], Márcia Ribeiro Maduro[4], Vanessa Coelho da Silva[5] and Wlademir Leite Correia Filho[6]

[1, 2, 4, 6] Department of Administration, State University of Amazonas – UEA, Manaus, Amazonas, Brazil.
[3] Department of Production Engineering, State University of Amazonas – UEA, Manaus, Amazonas, Brazil.
[5] Department of Intellectual Property, Technology Transfer and Innovation - PROFINIT/UEA, State University of Amazonas – UEA, Manaus, Amazonas, Brazil.

[1] http://orcid.org/0009-0003-1176-2932, [2] http://orcid.org/0000-0002-0621-9711, [3] http://orcid.org/0000-0003-1007-0734,
[4] http://orcid.org/0000-0002-4730-6002, [5] http://orcid.org/0009-0007-0006-3705, [6] http://orcid.org/0000-0003-4701-9027,

Email: rafaelabarbosa45@icloud.com, epteixeira@uea.edu.br, *olima@uea.edu.br, rmaduro@uea.edu.br, vcsilva@uea.edu.br, wfilho@uea.edu.br

ARTICLE INFO

Article History
Received: December 13th, 2023
Revised: December 27th, 2023
Accepted: December 28th, 2023
Published: December 30th, 2023

Keywords:
Process management,
Mapping,
Bottlenecks,
Improvement Proposals.

ABSTRACT

The objective of the study was to analyze, from the perspective of process management, the bottlenecks in lease contracts at the Public Defender's Office of the State of Amazonas. It consists of an applied case study, with a descriptive qualitative approach, using Business Process Management (BPM) as the guiding methodology and the 5W1H quality tool to suggest improvements in the processes. The results identified the main bottlenecks as the lack of procedure and flowchart development, absence of a schedule for opening branches, low synergy and communication among employees, as well as a lack of clear roles for those responsible for the processes. It is considered that through process mapping and bottleneck identification, it was possible to propose the following actions to ensure the continuous improvement of the process: development of procedures and flows, organizational climate research, meetings to understand departmental demands, and the creation of an opening schedule for processes and alignment of deadlines.

I. INTRODUCTION

According to Teixeira [1], "process mapping is an essential management and communication tool for leaders and organizations that want to promote improvements or implement a structure focused on new processes." For [2], public procurement processes are generally slow and bureaucratic. Therefore, implementing process management allows for documentation with a better understanding of workflow, role definitions, resulting in greater control over actions and improved process quality. Hence, public institutions should engage in intensive studies to provide excellent services.

The Public Defender's Office of the State of Amazonas plays a crucial role in providing access to justice, offering the opportunity for low-income individuals to resolve their legal conflicts, either judicially or extrajudicially, in various areas of law. Therefore, there is a need to provide high-quality services and optimize resources.

To meet this demand, the institution has its administrative headquarters and several units located in the capital of the Amazonas state. The entity is also undergoing an internalization process aimed at bringing the work of the DPE-AM closer to the rural population. Thus, the organization currently has 12 (twelve) branches in rural areas covering 48 municipalities and a population of 1.6 million people in the regions of Baixo and Médio Amazonas, Alto and Médio Solimões, Alto Rio Negro, Madeira and Médio Madeira, Purus, Maués, Coari, and Rio Negro-Solimões. Based on this expansion, the organization recognized the need to adapt and improve its processes, as not all demands can be met in the current way.

According to Gonçalves [3], the major challenge for organizations, whether public or private, is to integrate diverse

organizational processes and efficiently manage business process management. In this context, the research problem is to analyze the bottlenecks in lease contracts at DPE-AM in order to seek improvement in the processes conducted in the support area, optimizing time, workflow, and standardizing activities.

The objective of the study was to analyze, from the perspective of process management, the bottlenecks in lease contracts at the Public Defender's Office of the State of Amazonas. To achieve this, the study aimed to select and identify a lease contract process at DPE-AM, map the selected process, identify existing bottlenecks, and propose improvements in the current processes, seeking institutional learning and aiming for the enhancement of institutional practices.

The study methodology was a case study, bibliographic, documentary, and field research. Concerning the research's nature, it was applied because it aims to generate new knowledge and apply it to solve specific problems, in this case, in the processes of the contracts sector of the Public Defender's Office of Amazonas State. According to Thiollent [4], "applied research focuses on problems present in the activities of institutions, organizations, groups, or social actors. It is engaged in diagnosis, problem identification, and solution-seeking."

In terms of objectives, it was descriptive research since it seeks to analyze and describe the facts and phenomena of the contracts in DPE-AM. According to Gil [5], descriptive research aims primarily to describe the characteristics of a particular population or phenomenon or establish relationships between variables.

From an approach perspective, it is qualitative research since, as Marconi and Lakatos [6] explain, qualitative research aims to analyze and interpret deeper aspects, describing the complexity of human behavior and providing more detailed analyses of investigations, attitudes, and behavioral trends.

Regarding procedures, it is a case study, bibliographic, documentary, and field research. According to Yin [7], "a case study is an empirical investigation of a contemporary phenomenon within its real-life context, where the boundaries between the phenomenon and the context are not clearly defined." Thus, this work seeks to understand an event and, at the same time, analyze theories that explain it.

The chosen research unit was the contracts sector of the Public Defender's Office of the State of Amazonas, located at Avenida André Araújo, No. 679 – Aleixo neighborhood, Manaus-AM. The object of study was the lease contracts signed by DPE-AM in the period 2021-2022. It is a non-probabilistic intentional sample by judgment, as it does not have mathematical or statistical justification, relying solely on the researcher's criteria.

Initially, documentary research was conducted to gather information on the current contracts of DPE/AM through the folders and systems used in the institution, Protón and SEI (Electronic Information System), and a lease contract process was selected for study, specifically the lease of the property for the establishment of the Careiro Castanho branch in the interior of Amazonas state. Additionally, direct observation was carried out to verify how the lease processes are perceived and handled in the contracts sector.

Subsequently, a questionnaire was developed to find out how employees perceive the processes and existing problems. Then, the lease processes were mapped using the Bizagi software, which uses BPMN (Business Process Model and Notation). Finally, the 5W1H quality tool was used to propose improvements in the current lease processes, aiming to optimize work in the sectors.

II. THEORETICAL FRAMEWORK

In this section of the article, topics related to processes, their concepts, and the importance of mapping these processes, as well as the use of quality tools to contribute to improvement proposals in organizational activities, will be discussed.

II.1 PROCESSES IN ORGANIZATION

All types of organizations, whether public or private, have processes that are essential. Like any important type of work, these processes go beyond transforming inputs into outputs and generate value for the user, encompassing aspects such as feedback and repeatability [3]. In this sense, the National Quality Foundation [8] defines a process as "a set of pre-established activities that, when executed in a predetermined sequence, will lead to an expected result that ensures meeting the needs and expectations of customers and other interested parties." Similarly, according to Palmeira [9], processes, in addition to being activities with inputs and outputs performed by people or systems, also aim to respond to the needs of an internal or external customer, thus being the grouping of operations that will lead to a specific end. Another definition, based on SharP and McDermott [10], is that a process is the means of organizing work and resources with the primary goal of providing a result, be it a product or service, adding value to the customer. The classification given by Gonçalves [3] categorizes processes into three types concerning the organization's objectives:

• Business processes: These are directed towards the company's field of action and are supported by other internal processes, generating a product or service that is perceived by a customer.

• Organizational processes: These encompass all processes geared towards the organization and facilitate coordinated functioning among various subsystems of the organization, ensuring adequate support for business processes.

• Managerial processes: These focus on managers and aim to measure and make performance adjustments necessary in the organization.

According to ABPMP [11], organizational processes are support processes and, therefore, should deliver value. The uniqueness of this type is that the value is delivered to other processes, the business processes. Despite not delivering direct value to the end customer, organizational processes have a direct impact on the activities performed in primary processes.

According to Damelio [12], "the structured analysis of these processes allows for the reduction of service costs and integration failures between systems, in addition to enabling an understanding of current processes, eliminating or simplifying processes that require changes." For Silva and Guedes [13]: "The impacts of rework on the business are quite significant, and therefore, efforts should be made to minimize these losses.".

II.2 PROCESS MAPPING

In today's context, formal documentation of organizational processes does not necessarily imply successful procedures, as the current demand for organizations leans towards a more graphical representation, namely process mapping [14].

Rizzetti [15] asserts that "it is vital for the organization's processes to be disclosed and understood by all stakeholders. In this sense, a useful tool to meet this demand is process mapping." According to Pavani Junior and Sucuguglia [16], process mapping or modeling is a graphical representation of process activity sequences, clearly and objectively indicating its structure and functioning.

Drawing from Moreira [17], the primary benefits of process mapping include process agility, standardization of procedures, improvement in communication, and assistance in risk management. According to De Melo [18], choosing mapping as an improvement tool, based on its principles when applied correctly, allows not only the documentation of all activities comprising a process but also the correction of any problematic activities. It serves as a tool that aids in identifying non-value-added activities.

Process mapping can take various forms, but currently, the most accepted and widely used notation is BPMN - Business Process Model and Notation. ABPMP [11] states that "the notation is a standardized set of symbols and rules that determine the meaning of these symbols. These notations are used to compose process modeling with figures and connectors, thereby facilitating the representation of the relationship between components in the mapped process.".

According to Sganderla [19], BPMN allows processes to be represented by the chaining of events and activities connected through connectors that demonstrate the sequence in which they are performed. According to Campos [20], this tool is a highly dynamic technique, enabling the mapping of numerous types of business processes. It is the most widely used notation in the corporate world and is integrated with major process management software.

II.3 QUALITY TOOL: 5W1H

According to Carpinetti [21], the quality tool or methodology 5W1H is an organizational tool and consists of displaying in a table format the answers to basic questions to show the actions for improvements. "This table consists of questions such as: What, where a description of what is being implemented is made; Why, where the justification for the implementation of the action is provided; Where, where the location of the action's implementation is described; Who, where those responsible for implementing the action are specified; When, where the start and end dates of the action are defined; How, where it is described how the action will be implemented; and How much, where the involved costs are indicated" [21].

According [22], the 5W1H tool can be defined as an organized document that identifies the actions and responsibilities of those who will execute them, through a questioning approach, capable of guiding the various actions that must be implemented and should be structured to allow quick identification of the elements necessary for the project's implementation. The 5W1H tool (What, Where, Why, Who, When, How) is a model tool with the capacity for effective planning of future actions. This tool is successful due to its ability to detail actions with descriptions of the activities, when these activities will be carried out, who will carry them out, how they will be carried out, where the activities will be executed, and the reasons for executing such activities [23].

III. METHODOLOGY

Based on [24], methodology is the logic of scientific procedures in their genesis and development, and therefore, it is not merely a "metrology" or technology of measuring scientific facts.

The research unit chosen was the contracts department of the Public Defender's Office of the State of Amazonas, located at Avenida André Araújo, No. 679 – Aleixo Neighborhood, Manaus - AM.

As for its nature, the research is applied, as it aims to generate new knowledge and apply it to solve specific problems, in this case, in the processes of the contract sector of the Public Defender's Office of Amazonas. According to Thiollent [4], "applied research is focused on the problems present in the activities of institutions, organizations, groups, or social actors. It is committed to the development of diagnostics, identification of problems, and searching for solutions."

Regarding the objectives, it is descriptive research, as it seeks to analyze and describe the facts and phenomena of the reality of contracts of DPE-AM. According to Gil [5], descriptive researches aim primarily at "describing the characteristics of a certain population or phenomenon or establishing relationships between variables."

From the point of view of the approach, it is qualitative research, since, as Marconi and Lakatos [6] explain, the qualitative approach deals with a research that presupposes analyzing and interpreting deeper aspects, describing the complexity of human behavior, and providing more detailed analyses on investigations, attitudes, and behavioral trends.

Regarding procedures, it is a case study, bibliographic, documentary, and field research. According to Yin [7], "the case study is an empirical investigation of a contemporary phenomenon within a real-life context, where the boundaries between the phenomenon and context are not clearly defined." Thus, this work seeks to understand an event and, at the same time, analyze theories that explain it.

The research unit chosen was the contracts department of the Public Defender's Office of the State of Amazonas, located at Avenida André Araújo, No. 679 – Aleixo Neighborhood, Manaus-AM, and its study object is the contracts made at DPE-AM in the period 2021-2022. It is an intentional non-probabilistic sample by judgment, as according to Gil [5], they do not have a mathematical or statistical basis, depending solely on the researcher's criteria.

Initially, documentary research was conducted to gather information on the current contracts of DPE/AM through the folders and systems used in the institution, Protón and SEI (Electronic Information System), and a contracting process for rental study was selected, the rental of the property for the implementation of the Careiro Castanho hub in the interior of the state of Amazonas. In addition, direct observation was made to verify how the rental processes are perceived and treated in the contracts department.

Subsequently, a questionnaire was created to understand how the employees perceive the processes and existing problems. Then, the mapping of rental processes was carried out using bizagi, which uses the BPMN notation (Business Process Model and Notation).

These allowed for the identification of the main bottlenecks, and after a situational diagnosis, to propose improvements in the processes to refine the institutional processes through content analysis to process the information, using the 5W1H tool for proposing improvements in the current rental processes aiming at the optimization of work in the sectors.

IV. RESULTS AND DISCUSSION

IV.1 RENTAL PROCESS OF INLAND PROPERTIES

According to Table 1, the Public Defender's Office of the State of Amazonas entered into 4 (four) rental contracts in 2021, three of which were for inland properties, and in 2022, 5 (five) contracts for the same purpose, two of which were for rentals in the inland areas. The contracts for inland rentals are illustrated in gray, as follows:

Table 1 – Rental Contracts Signed in 2021 and 2022.

Contract Year	Contract No.	Object	Contract Year	Contract No.	Object
2021	07/2021	Property rental in the municipality of Lábrea/AM	2022	02/2022	Property rental in the municipality of Manaus/AM - Galpão
2021	14/2021	Property rental in the municipality of Manicoré/AM	2022	03/2022	Property rental in the municipality of Manaus/AM – Belo Horizonte
2021	27/2021	Property rental in the municipality of São Gabriel da Cachoeira/AM	2022	14/2022	Property rental in the municipality of Careiro Castanho/AM
2021	31/2021	Rental of 18 parking spaces located on Rua 24 de Maio	2022	22/2022	Location of Shopping Manaus Via Norte in the city of Manaus/AM
-	-	-	2022	33/2022	Rental of urban property measuring approximately 80 m2 (eighty square meters), located on Rodovia Carlos Braga, km 0, Iranduba/AM

Source: Authors, (2023).

Additionally, the DPE-AM (Public Defender's Office of the State of Amazonas) signed 4 (four) technical cooperation agreements in 2022 with several municipalities in Amazonas, with the purpose of improving the performance of the institutional activities of the Public Defender's Office in these inland municipalities, through the provision of rooms for the Public Defender's Office to carry out its activities, the so-called Inland Decentralized Units (UDIs).

According to preliminary analysis, the processes follow similar flows, and the main objective of this work is to analyze, from a process management perspective, the bottlenecks in the rental contracts of the Public Defender's Office. Thus, one process was selected to serve as the subject of this study.

The process chosen for the study was the procedural flow of renting property to accommodate the Public Defender's Office of the State of Amazonas' hub in the inland, in the municipality of Careiro Castanho. It should be noted that the analyzed process is directly aligned with resolutions No. 31/2017 and No. 33/2017, which create and regulate the service hubs, as well as the objectives of the institution's strategic planning for the period 2021-2024, specifically with objective 12, which aims to expand the process of DPE-AM's expansion in the interior, capital, in itinerant actions both physically and virtually.

For this purpose, data from the systems administratively used in the institution and commonly used for procedural instruction were used: Próton, Electronic Information System (SEI), and files in the Public Defender's Office network folder. Therefore, this selection comes from direct observation that notes the significant difficulties in following procedural steps from the initial phase to the contract's supervision itself, a continuous act after the contractual formalization. This perspective confirms the need to analyze this type of process and find the best sequence of steps to meet the expectations and needs of stakeholders. This assertion aligns with the definition of the National Quality Foundation [8], which defines processes as a "set of pre-established activities that, executed in a determined sequence, will lead to an expected result that ensures the meeting of the needs and expectations of customers and other interested parties."

The property rental contract is usually formalized between the DPE-AM and an individual or legal entity; in the case of Careiro Castanho, it was signed with an individual and occurs through a bidding waiver. The clauses contain the main characteristics of the contract, such as the object, duration, and obligations of the lessor and lessee. It should be noted that at the time of this study's elaboration, the contracts are still based on law 8.666/1993.

In the current perspective, the processes are not mapped, and the flow is not well defined, so the employees and departments that do not understand the process systemically end up generating incorrect documents in the system and consequently, rework, which reflects in delays in completing the process, among other bottlenecks presented later. According to Silva and Guedes [13]: “the impacts of rework on the business are quite significant, and therefore, these losses should be minimized as much as possible.”

Moreover, this type of process needs to be strategically studied, as it is directly linked to the mission of the institution: "to guarantee, as an agent of social transformation, comprehensive and free legal assistance to people in situations of vulnerability, promoting human rights and reducing social inequalities."

Thus, with the mapping of the rental process, it is possible to identify the bottlenecks and then propose the improvement actions to be implemented in the Public Defender's Office to optimize the processes.

IV.2 MAPPING OF THE RENTAL PROCESS AND IDENTIFIED BOTTLENECKS

In this stage, from the results of the questionnaire, it was possible to characterize and identify the degree of knowledge of the actors through whom the rental process passes and their perception of how these activities occur and the points to be improved.

When responding to their level of knowledge of the rental process, on a scale of 0 to 5, 75% of the total of 8 participants confirmed knowing the process at level 4 or 5, as shown in the figure 1.

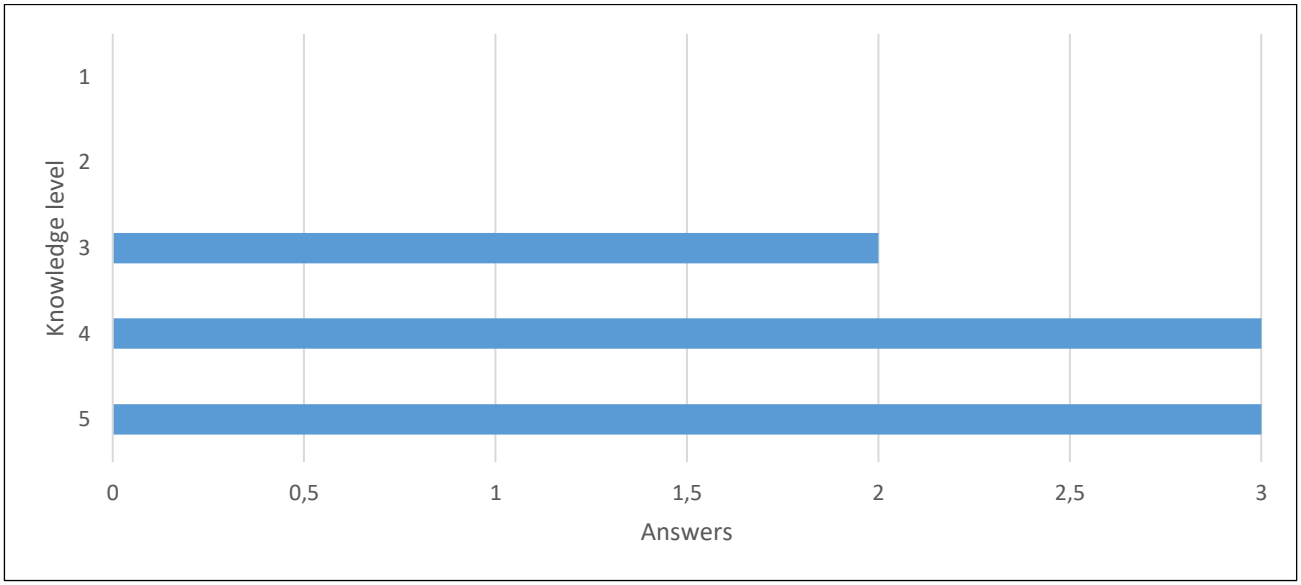


Figure 1 - Level of Knowledge of the Rental Process by the Actors.
Source: Authors, (2023).

While it is observable that the respondents characterize themselves as knowledgeable about the process, the majority state that there is a need for standardization of procedures, as well as a clearer and more dynamic definition of tasks, with the aim of better defining the stages and responsibilities of the respective actors in each sector. Nowadays, institutions formally documenting their processes does not equate to successful procedures, since the current requirement of organizations is a more graphical presentation, that is, process mapping [14].

Today, institutions formally documenting their processes does not mean successful procedures, as the current requirement of organizations is a more graphical representation, namely process mapping [14]. In this regard, according to the respondents, concerning the existing characteristics in the current rental process, 62.5% stated that there is no process mapping, which also generates vulnerability for the institution, as it is impossible to know the step-by-step of the process in the Public Defender's Office. Meanwhile, 25% claim that the information is conflicting, meaning that diagnosing the process leads to the conclusion of a lack of standardization and insufficient mapping to understand the essence of the process.

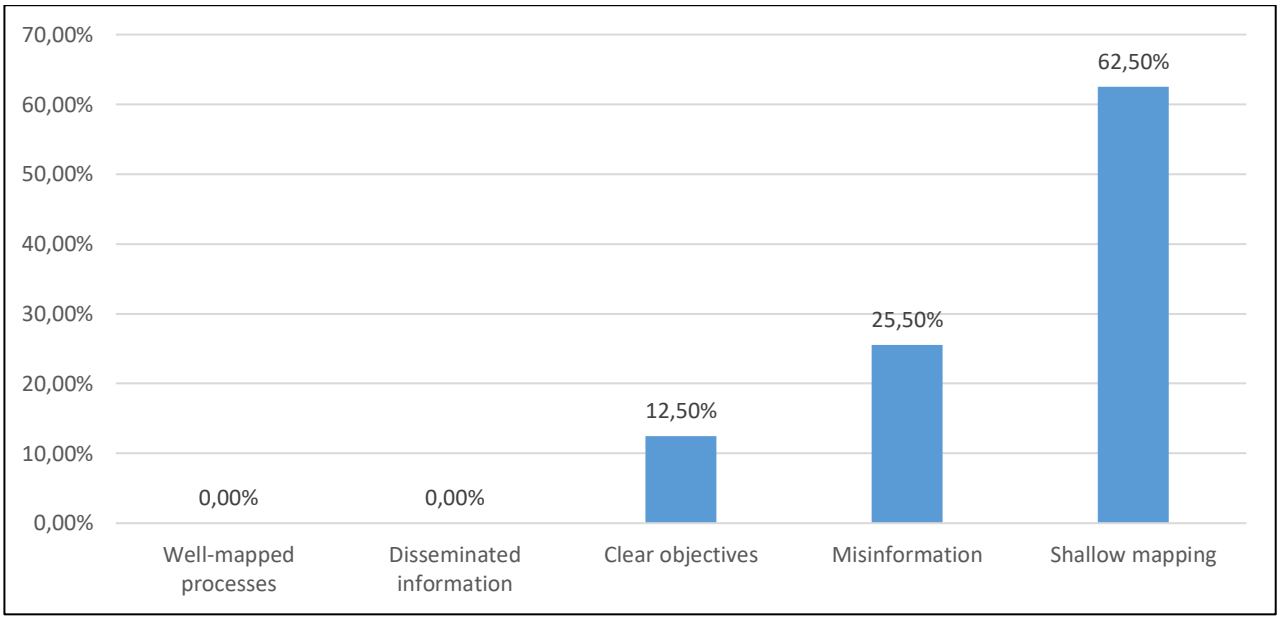


Figure 2 - Characteristics of the rental process.
Source: Authors, (2023).

A significant point is that many of the survey participants stated there are employees or departments possessing knowledge that is not disseminated, resulting in dependence and vulnerability of the institution. Chaves [25] asserts that "processes must be recorded and not just remain in the memory of the employees." Thus, Gissoni [26] highlights process mapping as a tool for recording processes.

Similarly, the actors of the process conclude that with the ingrained culture and resistance of employees to change and innovation, those involved do not fully understand the process. Contributing to this topic, Rizzetti [15] states that “it is vital that

the organization's processes be disclosed and understood by all involved. In this sense, a useful tool to meet this demand is process mapping."

In addition to this response, the survey participants also conclude that the advantages of mapping are numerous, such as the reduction of errors and rework, improved flow and speed in processing, standardized dissemination of information to those involved, and better visualization for decision-making. Based on Moreira [17], the main benefits of process mapping are agility in processes, standardization of procedures, improvement in communication, and assistance in risk management.

According to Pavani Junior and Sucuculglia [16], process mapping or modeling is a graphical representation of the sequences of activities in processes, indicating, in a clear and objective manner, their structure and functioning. Thus, mapping is a tool that allows for a broad visualization of the process, enabling the identification of value activities and tasks that are subject to change and elimination, with the aim of improving the procedural flow.

In this context, from the observation of procedural flows, an attempt was made to understand how the process works in the institution, through BPMN modeling. As stated by [20], this tool is a very dynamic technique, as it allows mapping numerous types of business processes, being the most used notation in the corporate world, integrated with the main process management software.

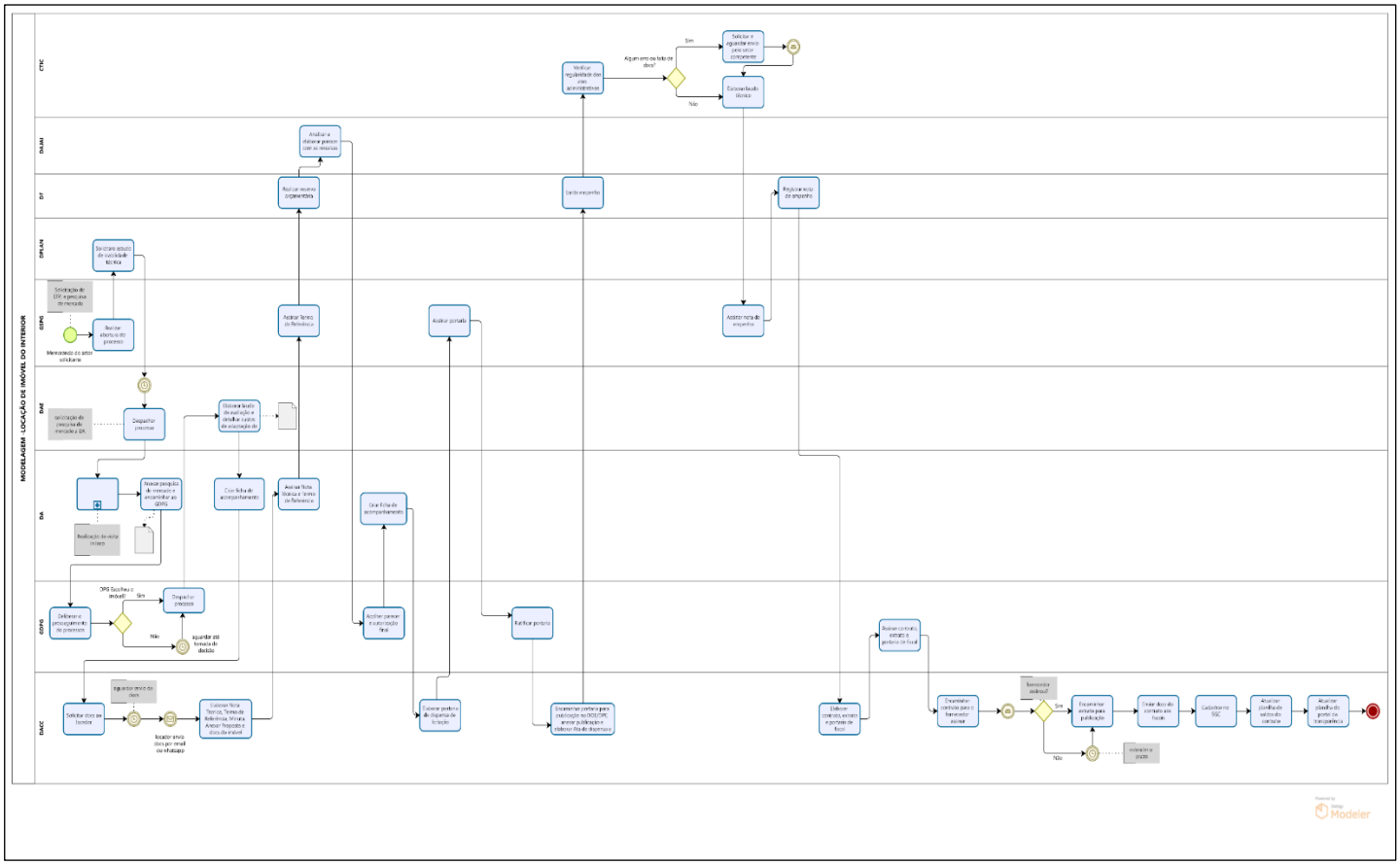


Figure 3 - Interior Property Rental Modeling.
Source: Authors, (2023).

Table 2 - Departments of DPE-AM.

ACRONYM	DESCRIPTION
CTIC	Internal Control
DACC	Deputy Directorate of Purchases and Contracts
DA	Administrative Directorate
DAJAI	Directorate of Legal Support and Institutional Affairs
DAE	Directorate of Architecture and Engineering
DF	Financial Directorate
DPLAN	Planning Directorate
GDPG	Office of the Public Defender General
GSPG	Office of the Deputy Public Defender General

Source: Authors, (2023).

Based on Damelio [12], analyzing processes in a structured way not only reduces integration failures between systems but also enables an understanding of current processes, the elimination, or simplification of processes that need changes. Thus, with the mapping carried out, the set of questionnaire responses, and the researcher's observation, it was possible to identify the main impediments to the progress of the Public Defender's Office's rental process.

The lack of development of procedures and flows to standardize processes, as well as the lack of synergy and communication between employees and top management, creates problems in the decision-making by the general public defender regarding the property, as the choice is based on market research, which in turn provides superficial information on these rentals. In this sense, according to Campos [27], standardization should be maintained within companies as something that will bring improvements in quality, cost, compliance with deadlines, safety, encouraging people to discuss what will be standardized, and establishing and adhering to the standard procedure. Furthermore, its alteration is encouraged as a means of improving processes.

This decision, based on the apparently most advantageous property, leads to various problems in the process, as from that moment on, those involved view the chosen rental as the only one capable of meeting the institution's demands. Consequently, any missing documentation or requirement from the landlord causes a stagnation in the process.

Another point related to communication and visibility of the departments is the lack of a schedule for initiating processes and, consequently, better alignment with the deadlines and goals of the strategic objective, as well as a better definition of the responsibilities of those involved. In line with De Melo [18], choosing mapping as a tool for improvement, based on its principles, when correctly employed, allows not only documenting all the activities that make up a process but also correcting any of these activities that are problematic, being a tool that aids in detecting non-value-adding activities.

Moreover, the paths for the institution's expansion need to be more planned and studied, to avoid hastily formalizing a contract, leading to future problems with incessant notifications to the landlord and work that could be avoided. Likewise, every department in the DPE-AM has its daily demands, and they usually become aware of this project and its urgency when the process moves to their process box, along with the demand for promptness in the activities to be carried out, which consequently leads to errors and rework.

IV.3 PROPOSAL FOR IMPROVEMENT ACTIONS

After creating the mapping of the existing process, analyzing the responses of the actors in the procedural flow, and identifying the bottlenecks, efforts were made to present improvements to be implemented, aimed at optimizing the execution of work in the departments. The compilation of this information enabled the use of the 5W1H tool, presented in the table below. Based on Pontes et al, [22], the 5W1H tool is defined as an organized document that presents the actions and responsibilities of those who will execute them, through questions capable of guiding the implementations, and has a structure that allows for quick identification of the elements necessary for the project's implementation.

Table 3: Application of the 5W1H Tool.

Bottlenecks	**5W**					**1H**
	What?	**Why?**	**Where?**	**When?**	**Who?**	**How?**
Lack of standardization of procedures and flows	Development of procedures and workflows	Avoid errors and rework	DPE-AM	Starting from 01/05/2023	Actors of the process	Present to the actors, the process mapping so that everyone is aware of the procedural flow
Knowledge that is not disseminated / Low synergy and communication among employees	Organizational climate research, meetings to understand the demands of the sectors and mapping of processes	Enhance the results and effectiveness of the work and reduce the dependency and vulnerability of the institution	Auditorium DPE-AM and online	Starting from 01/05/2023	Administrative staff	Meetings with a feedback policy and presentation of the mappings
Absence of a schedule for opening the hubs	Preparation of a schedule for opening processes and alignment of deadlines"	Greater organization and estimation of appropriate timelines for the start and end of the validity period	DPE-AM	Starting from 15/04/2023	Public Defender General, Planning Directorate, Administrative Directorate, and actors of the process	Meetings to set up a schedule for the opening of the centers

Source: Authors, (2023).

The development of procedures and workflows is necessary to guide, standardize, and optimize the process of renting properties from third parties by the Public Defender's Office of the State of Amazonas. This will be possible after the actors meet, understand the mapping carried out in this work, propose improvements, and eliminate non-value-adding steps in the process. Once they are aware of this mapping, they will also know the roles of each sector, facilitating the work and also the explanation for future employees who will develop activities in the said process.

To improve the synergy and communication of the employees, as well as to increase the effectiveness of the work carried out, it is necessary for the institution to hold regular meetings to understand the demands of the sectors and employees. Furthermore, conducting an organizational climate survey will enable the public agency's management to understand what their employees think, identify areas for improvement, and develop an action plan based on these findings.

The development of a schedule for the opening of processes and alignment of deadlines needs to be discussed, as with the strategic planning already in place, the centers that will be inaugurated and the deadlines to achieve these goals are known. Therefore, the creation of a document predicting these dates would be feasible for the planning of those responsible for the property rental process. The planning director, along with the general public defender and the administrative director, can meet to discuss the dates and determine the schedule for opening processes.

V. CONCLUSIONS

The main objective of this research was to analyze, through the perspective of process management, a rental contract of the Public Defender's Office of the State of Amazonas, identifying bottlenecks and suggesting actions for improvement, with the aim of optimizing these processes.

It was observed in the identification of rental processes how important they are for the development of the institution's activities, and that even though the workflows were similar, the main difficulties were found in following the procedures regularly.

It is noted that the process mapping was efficient in highlighting the bottlenecks. During the analysis for the mapping, it was observed that the actors were not aware of their respective tasks, the employees had poor communication and low synergy, which generated rework in the sectors. With the mapping of the rental process, it was also possible to verify that despite being foreseen in the strategic planning of the institution, there was no schedule for opening these processes, which also generated rework, as it had always been a test experience.

It is observed that once the work is defined, as per the presented mapping, the proposals for improvements directly address the causes of the problems and allow proceeding to the next step of optimizing these processes, the standardization that allows all sectors to be aware of the tasks to be carried out in the process.

It is worth mentioning that BPMN notation proved effective in the chosen process to be mapped, as did the Bizagi Modeler software, which was intuitive for modeling and easy to visualize for the process actors. Moreover, even though the objectives were achieved, the present work had a limitation: the lack of practical results from the presented proposals prevented a conclusive analysis of the study.

Therefore, it is suggested that the institution analyze the improvement proposals in order to implement them in the property rental processes of the Public Defender's Office of the State of Amazonas. Finally, it is suggested that process mapping be used in the other administrative processes of the institution to identify their bottlenecks, optimizing these activities and consequently contributing to the advancement of the public agency.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Rafaela Barbosa Nascimento, Elton Pereira Teixeira, Orlem Pinheiro de Lima, Márcia Ribeiro Maduro, Vanessa Coelho da Silva, Wlademir Leite Correia Filho.
Methodology: Rafaela Barbosa Nascimento, Elton Pereira Teixeira, Orlem Pinheiro de Lima, Márcia Ribeiro Maduro, Vanessa Coelho da Silva, Wlademir Leite Correia Filho.
Investigation: Rafaela Barbosa Nascimento, Elton Pereira Teixeira, Orlem Pinheiro de Lima, Márcia Ribeiro Maduro, Vanessa Coelho da Silva, Wlademir Leite Correia Filho.
Discussion of results: Rafaela Barbosa Nascimento, Elton Pereira Teixeira, Orlem Pinheiro de Lima, Márcia Ribeiro Maduro, Vanessa Coelho da Silva, Wlademir Leite Correia Filho.
Writing – Original Draft: Rafaela Barbosa Nascimento.
Writing – Review and Editing: Elton Pereira Teixeira, Orlem Pinheiro de Lima, Márcia Ribeiro Maduro, Vanessa Coelho da Silva, Wlademir Leite Correia Filho.
Resources: Rafaela Barbosa Nascimento.
Supervision: Elton Pereira Teixeira, Orlem Pinheiro de Lima, Márcia Ribeiro Maduro, Vanessa Coelho da Silva, Wlademir Leite Correia Filho.
Approval of the final text: Rafaela Barbosa Nascimento, Elton Pereira Teixeira, Orlem Pinheiro de Lima, Márcia Ribeiro Maduro, Vanessa Coelho da Silva, Wlademir Leite Correia Filho.

VII. REFERENCES

[1] TEIXEIRA, Ana Luisa Alves. Process Mapping: Theory and Illustrative Case. 2013.

[2] BRANCO, G.M.; BRODBECK, A. F.; TORRES, I. S. Structuring the Procurement Process in Government Organizations: The Case of a Federal Higher Education Institution. In: INFORMATION AND COMMUNICATION TECHNOLOGY WORKSHOP OF THE FEDERAL INSTITUTIONS OF HIGHER EDUCATION, 07, 2013, João Pessoa. Proceedings... João Pessoa, 2013.

[3] GONÇALVES, José Ernesto Lima. Companies are Large Collections of Processes. Business Administration Review, v. 40, no. 1, pp. 6-9, 2000.

[4] THIOLLENT, M. Action Research Methodology. São Paulo: Saraiva, 2009.

[5] GIL, Antonio Carlos. How to Develop Research Projects. 5th Ed. São Paulo: Atlas, 2008

[6] LAKATOS, Eva Maria; MARCONI, Marina de Andrade. Fundamentals of Scientific Methodology. 7th ed. São Paulo: Atlas, 2010.

[7] YIN, Robert K. Case Study: Planning and Methods. Porto Alegre: Bookman, 2001.

[8] FNQ – NATIONAL QUALITY FOUNDATION. Introduction to the Management Excellence Model – MEG®. São Paulo: National Quality Foundation, 2008.

[9] PALMEIRA, Andressa Fernandes. Proposal for a Procedures Manual for Payment of Student Aids at the Federal University of Espírito Santo. Dissertation. (Professional Master in Public Management) - Federal University of Espírito Santo. Vitória, p.99, 2016.

[10] SHARP, A.; MCDERMOTT, P. Workflow Modeling: Tools for Process Improvement and Application Development, Second Edition. 2009.

[11] ABPMP, Brazil. Guide to Business Process Management - BPM CBOK, v. 3, 2013.

[12] DAMÉLIO, R. (2011) The Basics of Process Mapping, 2nd Edition, ISBN10:1363273764, CRC Press.

[13] SILVA, Ana Karoline da; GUEDES, Eduardo Emanuel Vieira. CONTROL OF REWORK INDEX: A Case Study in an Automotive Company. 2019.

[14] ZABJEK, D.; KOVACIC, A; STEMBERGER, M. I. The Influence of Business Process Management and Some Other Critical Success Factors on Successful ERP Implementation. Business Process Management Journal, v. 15, pp. 588-608, 2009.

[15] RIZZETTI, Daniele Medianeira. Standardization of Processes and Routines of the Payment System Control and Maintenance Core. 2014. 160f. Dissertation. (Professional Master in Public Organizations Management) - Federal University of Santa Maria, RS. 2014.

[16] PAVANI JUNIOR, Orlando; SCUCUGLIA, Rafael. Mapping and Management by Processes – BPM. São Paulo: M. Books, 2011.

[17] MOREIRA, Elzeni Alves. Management and Mapping of Processes in Public Institutions: A Case Study in the Personnel Administration Directorate of the Federal University of Rio Grande do Norte. 2016. 106f. Dissertation - Federal University of Rio Grande do Norte. Natal, 2016.

[18] DE MELO, A. E. N. S. Application of Process Mapping and Simulation in the Development of Productive Process Projects. Itajubá: UNIFEI, 2008.

[19] Sganderla, M. A., & Lacerda, G. S. MELHORANDO A GERÊNCIA E A CONSTRUÇÃO DE SOFTWARE COM METODOLOGIAS ÁGEIS.

[20] AGUIAR, Wellington Sousa; DAMASCENO, Mariana; MELO, Francisco. Evaluation of Free BPMN Softwares for Process Mapping. In: NATIONAL CONGRESS OF EXCELLENCE IN MANAGEMENT. 12th, Sept 29-30, 2016. Rio de Janeiro. Proceedings... Rio de Janeiro: INOVARSE, 2016.

[21] CARPINETTI, L. C. R. Proposal of a Conceptual Model for the Deployment of Strategic Improvements. Management & Production, v. 7, no. 1, pp. 29-42, 2000.

[22] PONTES, H. L. J; et al. (2005). Improvement in the Productive System of a Coffee Factory: A Case Study. In Production Engineering Symposium, 12, Bauru. Proceedings. São Paulo: SIMPEP, 2005.

[23] Almeida, D., Machado, D., Andrade, J. C., Mendo, S., Gomes, A. M., & Freitas, A. C. (2020). Evolving trends in next-generation probiotics: a 5W1H perspective. Critical reviews in food science and nutrition, 60(11), 1783-1796.

[24] BRUYNE, P. D., HERMAN, J., & SCHOUTHEETE, M. (1991). Dinâmica da pesquisa em ciências: os polos da prática metodologia. Rio de Janeiro: F. Alves.

[25] CHAVES, Gustavo Henrique Pessoa. Process Management and Gespública: Approaches for Managing a Stricto Sensu Postgraduate Program at UFG. 2016. 101f. Dissertation. (Master in Public Administration- PROFIAP) - Federal University of Goiás. Goiânia, 2016.

[26] GISSONI, L. R. D. M. (2016). Implantação de mapeamento de processos de trabalho no Setor de Transporte de uma instituição federal de ensino.

[27] CAMPOS, Vicente Falconi. Total Quality: Standardization of Companies. Belo Horizonte: EDG, 1999.