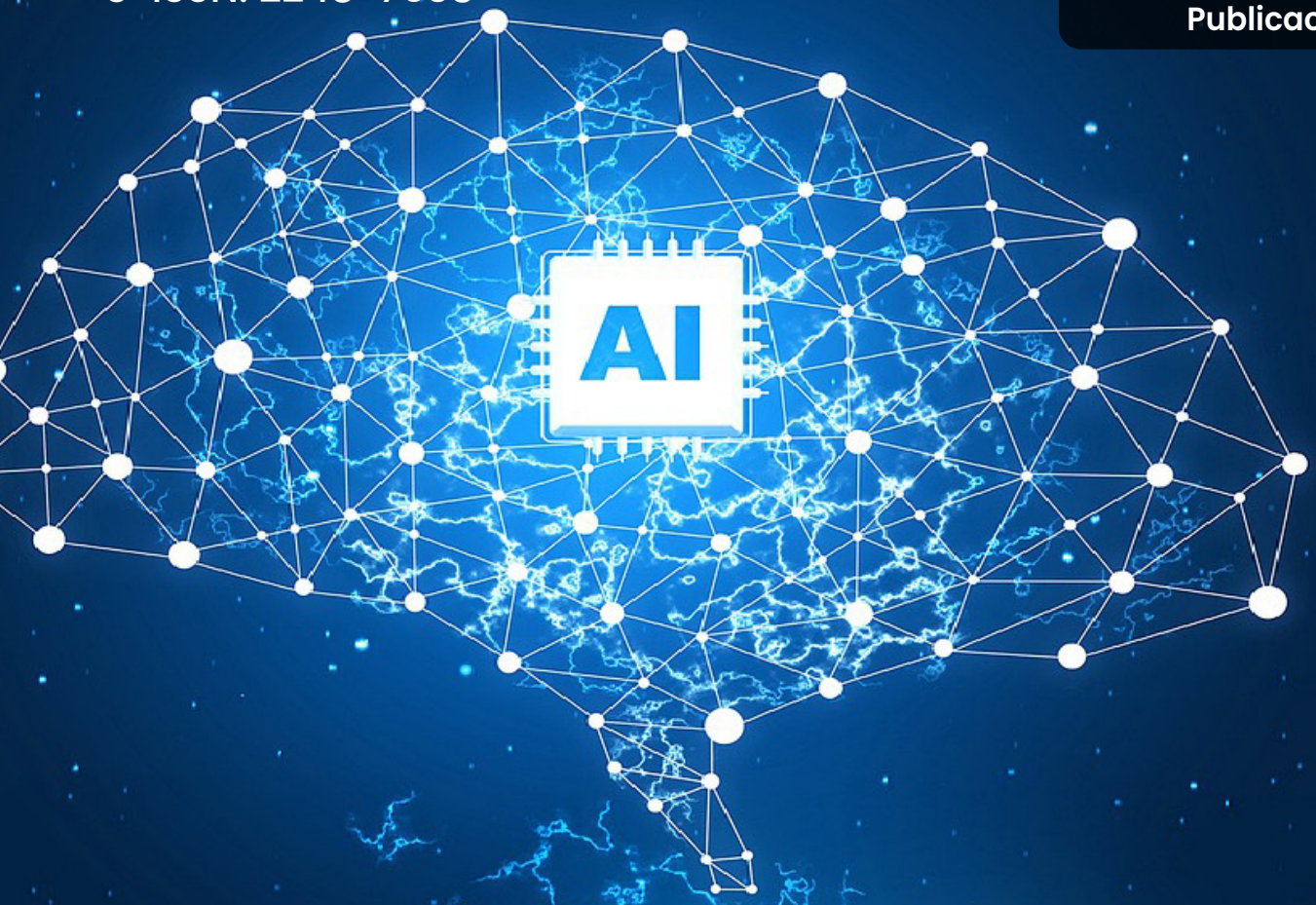
Revista de Tecnología y Cultura

TECNURA

V.27 N.°78

ISSN: 0123-921X
e-ISSN: 2248-7638

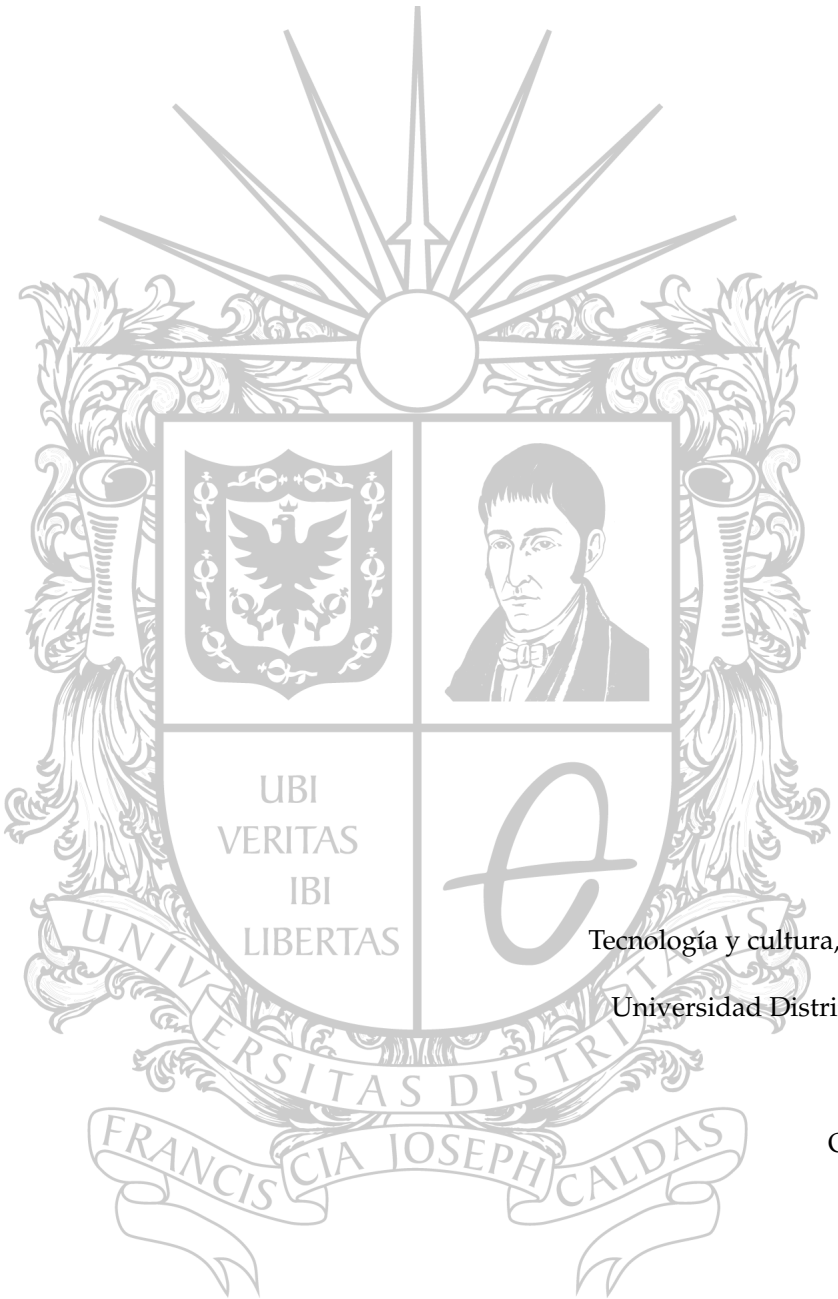
Octubre - Diciembre de 2023
Publicación trimestral



UNIVERSIDAD DISTRITAL
FRANCISCO JOSÉ DE CALDAS
Facultad Tecnológica

Revista de Tecnología y Cultura
TECNURA

ISSN: 0123-921X / e-ISSN: 2248-7638
Volumen 27 - Número 78



Tecnura

Tecnología y cultura, afirmando el conocimiento

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REVISTA TECNURA
La revista Tecnura es una publicación institucional de la Facultad Tecnológica de la Universidad Distrital Francisco José de Caldas de carácter científico-tecnológico, arbitrada mediante un proceso de revisión entre pares de doble ciego. La periodicidad de la conformación de sus comités Científico y Editorial está sujeta a la publicación de artículos en revistas indexadas internacionalmente por parte de sus respectivos miembros.

PERIODICIDAD
Es una publicación de carácter científico-tecnológico con periodicidad trimestral, que se publica los meses de enero, abril, julio y octubre. Su primer número apareció en el segundo semestre del año 1997 y hasta la fecha ha mantenido su regularidad.

COBERTURA TEMÁTICA
Las áreas temáticas de interés de la revista Tecnura están enfocadas a todos los campos de la ingeniería, como la electrónica, telecomunicaciones, electricidad, sistemas, industrial, mecánica, catastral, civil, ambiental, entre otras. Sin embargo, no se restringe únicamente a estas, también tienen cabida los temas de educación y salud, siempre y cuando estén relacionados con la ingeniería. La revista publicará únicamente artículos de investigación científica y tecnológica, de reflexión y de revisión.

MISIÓN
La revista Tecnura tiene como misión divulgar resultados de proyectos de investigación realizados en el área de la ingeniería, a través de la publicación de artículos originales e inéditos, realizados por académicos y profesionales pertenecientes a instituciones nacionales o extranjeras del orden público o privado.

PÚBLICO OBJETIVO
La revista Tecnura está dirigida a docentes, investigadores, estudiantes y profesionales interesados en la actualización permanente de sus conocimientos y el seguimiento de los procesos de investigación científico-tecnológica, en el campo de la ingeniería.

INDEXACIÓN
Tecnura es una publicación de carácter académico indexada en los indices regionales publindex indexada y clasificada en categoria B, Scielo Colombia y Redalyc (México); además de las siguientes bases bibliográficas: INSPEC del Institution of Engineering and Technology (Inglaterra), Fuente Académica Premier de EBSCO (Estados Unidos), CABI (Inglaterra), IndexCorpernicus (Polonia), Informe Académico de Gale Cengage Learning (México), Periódica de la Universidad Nacional Autónoma de México (México), Oceanet (España) y Dialnet de la Universidad de la Rioja (España); también hace parte de los siguientes directorios: Sistema Regional de Información en Línea para Revistas Científicas de América Latina, el Caribe, España y Portugal Latindex (México); Índice Bibliográfico Actualidad Iberoamericana (Chile), e-Revistas (España), DOAJ (Suecia), Ulrich de Proquest (Estados Unidos).

FORMA DE ADQUISICIÓN
La revista Tecnura se puede adquirir a traves de canje o suscripcion en el portal de la de la revista.

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Director y Editor Revista Tecnura
Sala de Revistas, Bloque 5, Oficina 305
Facultad Tecnológica
Universidad Distrital Francisco José de Caldas
Dirección: Cl. 68d Bis A Sur # 49 F - 70, Bogotá
Teléfono: 571–3239300
Bogotá, D.C., Colombia
Correo electrónico:
tecnura.ud@udistrital.edu.co
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Tecnura
Volumen 27 - Número 78

TECNURA Journal
Technology And Culture, Affirming Knowledge
District University Francisco José De Caldas
Faculty Of Technology

p-ISSN: 0123-921X - e-ISSN: 2248-7638

Tecnura
Octubre - Diciembre de 2023

TECNURA JOURNAL

Tecnura Journal is an institutional scientific-technological publication from the Faculty of Technology at District University Francisco José de Caldas, arbitrated by means of a double-blinded peer review process. The periodicity for its Scientific and Editorial committees line-up is subject to the publication of articles in internationally indexed magazines by its own members.

PERIODICITY

Tecnura journal is a scientific-technological publication with quarterly periodicity, published in January, April, July and October. Its first edition appeared in the second term, 1997 and its editions have normally continued from that year and on.

THEMATIC COVERAGE

The thematic areas of interest at Tecnura journal are focused on all fields of engineering such as electronical, telecommunications, electrical, computer, industrial, mechanical, cadastral, civil, environmental, etc. However, it is not restricted to those, there is also room for education and health topics as well, as long as they are related to engineering. The journal will only publish scientific and technological research, reflection and review articles.

MISSION

Tecnura journal is aimed at publishing research project results carried out in the field of engineering, through the publishing of original and unpublished articles written by academics and professionals from national or international public or private institutions.

TARGET AUDIENCE

Tecnura journal is directed to professors, researchers, students and professionals interested in permanent update of their knowledge and the monitoring of the scientific-technological research processes in the field of engineering.

INDEXING

Tecnura is an academic publication indexed in the Regional Index Scielo Colombia (Colombia) and Redalyc (México); as wel as the following bibliographic databases: INSPEC of the Institution of Engineering and Technology (England), Fuente Académica Premier of EBSCO (United States), CABI (England), Index Copernicus (Poland), Informe Académico of Gale Cengage Learning (México), Periódica of the Universidad Nacional Autónoma de México (México), Oceanet (Spain) and Dialnet of the Universidad de la Rioja (Spain); it is also part of the following directories: Online Regional Information System for Scientific journals from Latin America, Caribbean, Spain and Portugal Latindex (México), bibliographic index Actualidad Iberoamericana (Chile), e-Revistas (Spain), DOAJ (Sweden), Ulrich of Proquest (United States).

FORM OF ACQUISITION

Tecnura journal is available through purchase, exchange or subscription.

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Enviar a Ph.D. Alexander Jiménez Triana
Director y Editor Revista Tecnura
Sala de Revistas, Bloque 5, Oficina 305
Facultad Tecnológica
Universidad Distrital Francisco José de Caldas
Dirección: Cl. 68d Bis A Sur # 49 F - 70, Bogotá
Teléfono: 571–3239300
Bogotá, D.C., Colombia
E-mail:
tecnura.ud@udistrital.edu.co
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STYLE CORRECTION IN SPANISH

MSc. Fernando Carretero Padilla

STYLE CORRECTION IN ENGLISH

MSc. Alexander Olave

TITLE PAGE DISEGN

Andrés Enciso

LAYOUT AND LaTeX* DESIGN

MSc. Julian Arcila-Forero

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Declaración de ética y buenas prácticas

https://revistas.udistrital.edu.co/index.php/Tecnura/about

El comité editorial de la revista **Tecnura** está comprometido con altos estándares de ética y buenas prácticas en la difusión y transferencia del conocimiento, para garantizar el rigor y la calidad científica. Es por ello que ha adoptado como referencia el Código de Conducta que, para editores de revistas científicas, ha establecido el Comité de Ética de Publicaciones (COPE: Committee on Publication Ethics) dentro de los cuales se destaca:

Obligaciones y responsabilidades generales del equipo editorial

En su calidad de máximos responsables de la revista, el comité y el equipo editorial de Tecnura se comprometen a:

- Aunar esfuerzos para satisfacer las necesidades de los lectores y autores.
- Propender por el mejoramiento continuo de la revista.
- Asegurar la calidad del material que se publica.
- Velar por la libertad de expresión.
- Mantener la integridad académica de su contenido.
- Impedir que intereses comerciales comprometan los criterios intelectuales.
- Publicar correcciones, aclaraciones, retractaciones y disculpas cuando sea necesario.

Relaciones con los lectores

Los lectores estarán informados acerca de quién ha financiado la investigación y sobre su papel en la investigación.

Relaciones con los autores

Tecnura se compromete a asegurar la calidad del material que publica, informando sobre los objetivos y normas de la revista. Las decisiones de los editores para aceptar o rechazar un documento para su publicación se basan únicamente en la relevancia del trabajo, su originalidad y la pertinencia del estudio con relación a la línea editorial de la revista. La revista incluye una descripción de los procesos seguidos en la evaluación por pares de cada trabajo recibido. Cuenta con una guía de autores en la que se presenta esta información. Dicha guía se actualiza regularmente y contiene un vínculo a la presente declaración ética. Se reconoce el derecho de los autores a apelar las decisiones editoriales. Los editores no modificarán su decisión en la aceptación de envíos, a menos que se detecten irregularidades o situaciones extraordinarias. Cualquier cambio en los miembros del equipo editorial no afectará las decisiones ya tomadas, salvo casos excepcionales en los que confluyan graves circunstancias.

Relaciones con los evaluadores

Tecnura pone a disposición de los evaluadores una guía acerca de lo que se espera de ellos. La identidad de los evaluadores se encuentra en todo momento protegida, garantizando su anonimato.

Proceso de evaluación por pares

Tecnura garantiza que el material remitido para su publicación será considerado como materia reservada

y confidencial mientras que se evalúa (doble ciego).

Reclamaciones

Tecnura se compromete responder con rapidez a las quejas recibidas y a velar para que los demandantes insatisfechos puedan tramitar todas sus quejas. En cualquier caso, si los interesados no consiguen satisfacer sus reclamaciones, se considera que están en su derecho de elevar sus protestas a otras instancias.

Fomento de la integridad académica

Tecnura asegura que el material que publica se ajusta a las normas éticas internacionalmente aceptadas.

Protección de datos individuales

Tecnura garantiza la confidencialidad de la información individual (por ejemplo, de los profesores y/o alumnos participantes como colaboradores o sujetos de estudio en las investigaciones presentadas).

Seguimiento de malas prácticas

Tecnura asume su obligación para actuar en consecuencia en caso de sospecha de malas prácticas o conductas inadecuadas. Esta obligación se extiende tanto a los documentos publicados como a los no publicados. Los editores no sólo rechazarán los manuscritos que planteen dudas sobre una posible mala conducta, sino que se consideran éticamente obligados a denunciar los supuestos casos de mala conducta. Desde la revista se realizarán todos los esfuerzos razonables para asegurar que los trabajos sometidos a evaluación sean rigurosos y éticamente adecuados.

Integridad y rigor académico

Cada vez que se tenga constancia de que algún trabajo publicado contiene inexactitudes importantes, declaraciones engañosas o distorsionadas, debe ser corregido de forma inmediata.
En caso de detectarse algún trabajo cuyo contenido sea fraudulento, será retirado tan pronto como se conozca, informando inmediatamente tanto a los lectores como a los sistemas de indexación.
Se consideran prácticas inadmisibles, y como tal se denunciarán las siguientes: el envío simultáneo de un mismo trabajo a varias revistas, la publicación duplicada o con cambios irrelevantes o parafraseo del mismo trabajo, o la fragmentación artificial de un trabajo en varios artículos.

Relaciones con los propietarios y editores de revistas

La relación entre editores, editoriales y propietarios estará sujeta al principio de independencia editorial.
Tecnura garantizará siempre que los artículos se publiquen con base en su calidad e idoneidad para los lectores, y no con vistas a un beneficio económico o político. En este sentido, el hecho de que la revista no se rija por intereses económicos, y defienda el ideal de libre acceso al conocimiento universal y gratuito, facilita dicha independencia.

Conflicto de intereses

Tecnura establecerá los mecanismos necesarios para evitar o resolver los posibles conflictos de intereses entre autores, evaluadores y/o el propio equipo editorial.

Quejas/denuncias

Cualquier autor, lector, evaluador o editor puede remitir sus quejas a los organismos competentes

Code of ethics and good practice

https://revistas.udistrital.edu.co/index.php/Tecnura/about

The editorial board of Tecnura journal is committed to ethics high standards and good practice for knowledge dissemination and transfer, in order to ensure rigour and scientific quality. That is why it has taken as reference the Code of Conduct, which has been established by the Committee on Publication Ethics (COPE) for scientific journal editors; outlining the following:

General duties and responsibilities of the editorial board

As most responsible for the journal, **Tecnura** committee and the editorial board are committed to:

- Joining efforts to meet the readers and authors' needs.
- Tending to the continuous improvement of the Journal.
- Ensuring quality of published material.
- Ensuring freedom of expression.
- Maintaining the academic integrity of their content.
- Prevent commercial interests compromise intellectual standards.
- Post corrections, clarifications, retractions and apologies when necessary.
- Relations with readers.
- Readers will be informed about who has funded re- search and their role in the research.

Relations with authors

Tecnura is committed to ensuring the quality of published material, informing the goals and standards of the journal. The decisions of publishers to accept or reject a paper for publication are based solely on the relevance of the work, originality and pertinence of the study with journal editorial line.
The journal includes a description of the process for peer evaluation of each received work, and has an authors guide with this information. The guide is regularly updated and contains a link to this code of ethics. The journal recognizes the right of authors to appeal editorial decisions Publishers will not change their decision in accepting or rejecting articles, unless extraordinary circumstances or irregularities are detected. Any change in the editorial board members will not affect decisions already made, except for unusual cases where serious circumstances converge.

Relations with evaluators

Tecnura makes available to reviewers a guide to what is expected from them. Reviewers' identity is protected at all times, ensuring anonymity.

Peer review process

Tecnura ensures that material submitted for publication will be considered private and confidential issue while being reviewed (double blind).

Claims

Tecnura is committed to respond quickly to complaints and ensure that dissatisfied claimant can process all complaints. In any case, if applicants fail to satisfy their claims, the journal considers that

they have the right to raise their protests to other instances.

Promoting Academic Integrity

Tecnura ensures that the published material conforms to internationally accepted ethical standards.

Protection of individual data

Tecnura guarantees the confidentiality of individual information (e.g. participant teachers and/or students as collaborators or subjects of study in the presented research).

Tracking malpractice

Tecnura accepts the obligation to act accordingly in case of suspected malpractice or misconduct. This obligation extends both to publish and unpublished documents. The editors not only reject manuscripts with doubts about possible misconduct, but they are considered ethically obligated to report suspected cases of misconduct. From the journal every reasonable effort is made to ensure that works submitted for evaluation are rigorous and ethically appropriate.

Integrity and academic rigour

Whenever evidence that a published work contains significant misstatements, misleading or distorted statements, it must be corrected immediately.
In case of any work with fraudulent content is detected, it will be removed as soon as it is known, and immediately informing both readers and indexing systems.
Practices that are considered unacceptable and as such will be reported: simultaneous sending of the same work to various journals, duplicate publication with irrelevant changes or paraphrase of the same work, or the artificial fragmentation of a work in several articles.

Relations with owners and journal editors

The relation between editors, publishers and owners will be subject to the principle of editorial independence. **Tecnura** will ensure that articles are published based on their quality and suitability for readers, and not for an economic or political gain. In this sense, the fact that the journal is not governed by economic interests, and defends the ideal of universal and free access to knowledge, provides that independence.

Conflict of interest

Tecnura will establish the necessary mechanisms to avoid or resolve potential conflicts of interest between authors, reviewers and/or the editorial board itself.

Complaints / allegations

Any author, reader, reviewer or editor may refer their complaints to the competent authorities.

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Tabla de Contenidos

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Editorial

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La famosa frase del filósofo presocrático Heráclito, "todo fluye", representa el cambio constante como característica intrínseca del universo. No hay nada permanente en el mundo, y las formas, así como las ideas, se modifican para reconocer la realidad y adaptarse a un mundo cambiante. No todo debe permanecer igual. La evolución es un motor universal, y siempre motiva el cambio. Genera una nueva versión de nuestra realidad, más genuina, más actual. Aristóteles por su parte, sostiene que todo el universo está compuesto por materia y forma, y el cambio requiere una causa, a veces debida a algún tipo de intervención externa que altera la forma de lo material. En contraposición a la idea de un perpetuo flujo de las cosas, el cambio no es inherente a ellas y no forma parte de su realidad. Esta dualidad cambio-realidad presente en las ideas de Heráclito y Aristóteles nos advierte sobre la complejidad del cambio y su papel en la comprensión de nuestra realidad.

El cambio es una fuerza esencial para el progreso y contribuye al desarrollo e innovación en diversos aspectos de nuestra vida. No solo está presente en las ideas evolutivas de Darwin, sino que también es la constante en las teorías sobre desarrollo económico y social de Keynes o Stiglitz, y es parte fundamental de la propuesta de Martin Luther King en su búsqueda de un mundo justo e igualitario. En las últimas décadas, los cambios a nivel científico y tecnológico han tenido profundas implicaciones y han revolucionado la manera en la que hacemos las cosas, desde los avances médicos para el diagnóstico y tratamiento de enfermedades, hasta la terapia génica como producto de la secuenciación del genoma humano. Nuestra vida ya no es la misma debido a la revolución digital, que ha cambiado la forma en la que nos comunicamos y vemos el mundo. Las tecnologías verdes emergentes están reduciendo la dependencia de los combustibles fósiles y ayudando a mitigar el cambio climático, haciendo nuestro medio ambiente más sostenible. El desarrollo de la inteligencia artificial nos cuestiona sobre nuestro futuro y los cambios que podríamos, como civilización, estar desencadenando. Recordando las ideas provocadoras de Harari, nuestra forma de gobernar el mundo basada en las cosas que imaginamos podría, paradójicamente, hacernos descender como la clase dominante.

Si bien los cambios pueden ser complejos y desafiantes, bien enfocados contribuyen al bienestar y el desarrollo de nuestra sociedad. Hoy soy parte del cambio en la revista Tecnura, iniciando un nuevo ciclo como su editor. Ahora tengo el privilegio de ser yo quien impulse nuevas transformaciones y

mejoras. Con esta nueva visión de la revista, mi compromiso es ser una causa eficiente para generar los cambios que requiere, y garantizar que se cumpla el objetivo de ser un medio de comunicación del conocimiento. La revista estará en constante evolución, permitiendo que las ideas se materialicen y fluyan. Transitaré este camino con políticas claras y total transparencia, abogando siempre por el crecimiento de la revista. Asumiré este desafío con la mejor actitud, sin trivializar la ardua tarea que representa.

¡Bienvenidos a este nuevo ciclo de Tecnura! Y gracias por permitirme ser parte de este cambio constante y enriquecedor.

Alexander Jiménez Triana

ajimenezt2@udistrital.edu.co

Editorial

https://revistas.udistrital.edu.co/index.php/Tecnura/issue/view/1201

The famous phrase of the pre-Socratic philosopher Heraclitus, "everything flows," represents constant change as an intrinsic characteristic of the universe. Nothing in the world is permanent, and forms, as well as ideas, change to recognize reality and adapt to a changing world. Not everything must remain the same. Evolution is a universal engine and always motivates change. It generates a new version of our reality, more genuine and more current. Aristotle argues that the entire universe is composed of matter and form, and change requires a cause, sometimes due to some external intervention that alters the form of the material. In contrast to the idea of a perpetual flow of things, change is not inherent to them and is not part of their reality. This duality of change-reality present in the ideas of Heraclitus and Aristotle warns us about the complexity involved in change.

Change is an essential force for progress and contributes to development and innovation in various aspects of our lives. It is not only present in Darwin's evolutionary ideas, but it is also a constant in the economic and social development theories of Keynes and Stiglitz, and it is a fundamental part of King's proposal in his quest for a just and equal world. In recent decades, changes at the scientific and technological levels have had profound implications and have revolutionized the way we do things, from medical advances for the diagnosis and treatment of diseases to gene therapy as a product of human genome sequencing. Our lives are no longer the same due to the digital revolution, which has changed the way we communicate and see the world. Emerging green technologies are reducing dependence on fossil fuels and helping to mitigate climate change, making our environment more sustainable.

The development of artificial intelligence questions us about our future and the changes that we, as a civilization, could be triggering. Remembering Harari's provocative ideas, our way of governing the world based on things we imagine could, paradoxically, lead us to descend as the ruling class. While changes can be complex and challenging, when well-focused, they contribute to the welfare and development of our society.

Today, I am part of the change at Tecnura magazine, starting a new cycle as its editor. Now, I have the privilege of being the one to drive new transformations and improvements. With this new vision for the magazine, I am committed to being an efficient force for generating the changes it requires

and ensuring that the objective of being a medium for the dissemination of knowledge is fulfilled. The magazine will be in constant evolution, allowing ideas to materialize and flow. I will continue this path with clear policies and complete transparency, always advocating for the growth of the magazine. I will take on this challenge with the best attitude, without trivializing the arduous task it represents.

Welcome to this new cycle of Tecnura! And thank you for allowing me to be part of this constant and enriching change.

Alexander Jiménez Triana
ajimenezt2@udistrital.edu.co

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Tecnura
https://revistas.udistrital.edu.co/index.php/Tecnura/issue/view/1201
DOI: https://doi.org/10.14483/22487638.18569

INVESTIGACIÓN

Optimal integration of D-STATCOMs in electrical distribution systems for investment and operating cost reduction by using a Master-Slave Methodology between GA/PSO

Integración óptima de D-STATCOMs en sistemas eléctricos de distribución para reducción de costos de inversión y operación utilizando una metodología Maestro-Esclavo entre el GA/PSO

Luis Fernando Grisales-Noreña [1], Edward Jhohan Marín-García [2], Carlos Alberto Ramírez-Vanegas [3]

Fecha de Recepción: 8 de septiembre de 2021 **Fecha de Aceptación**: 28 de abril de 2022

Cómo citar: Grisales-Noreña, L.F., Marín-García, E.J. y Ramirez-Vanegas, C.A. (2023). Optimal Integration of D-STATCOMs in Electrical Distribution Systems for Investment and Operating Cost reduction by Using a Master-Slave Methodology Between GA/PSO. *Tecnura*, **27**(78), 16-41. https://doi.org/10.14483/22487638.18569

ABSTRACT

Objective: The objective of this paper is to propose a methodology for the optimal location and sizing of D-STATCOMs within a distribution electrical system, with the aim to reduce the annualized operating costs related to the annual power energy losses and the investment costs associated with the installation of the D-STATCOM.

Context: This paper presents a hybrid methodology based on a master-slave strategy and the genetic and particle swarm optimization algorithms for solving the problem of optimal location and sizing of Distribution Static Compensators (D-STATCOMs), for reactive compensation in electrical distribution systems.

Methodology: In this paper was used a mathematical formulation that represents the effect of the location and sizing of D-STATCOMs in electrical distribution systems; by proposing a master-slave methodology combining the genetic algorithm and the particle swarm optimization algorithms as a solution method. Furthermore, with the aim to validate the effectiveness and robustness of the proposed methodology in this work, three comparison methods, two test systems, and multiple technical considerations were used to represent the electrical distribution systems in a distributed energy resource

[1]Doctor en energías renovables de la Universidad de Jaén-España. Doctor en ingeniería automática de la Universidad Nacional de Colombia. Magíster en Ingeniería Eléctrica e Ingeniero Electricista de la Universidad Tecnológica de Pereira. Docente de la Universidad de Talca. Curíco,Chile.
Email: luis.grisales@utalca.cl
[2]Tecnólogo Electrónico e Ingeniero Electrónico de la Universidad del Quindío. Magíster en Ingeniería Eléctrica de la Universidad Tecnológica de Pereira. Docente asociado de la Universidad del Valle sede Cartago y líder del Grupo de Investigación en Innovación y Desarrollo en Electrónica Aplicada -GiiDEA, Cartago, Colombia.
Email: marin.edward@correounivalle.edu.co
[3]Magíster en Ingeniería Eléctrica, Ingeniero Electricista. Docente Universidad Tecnológica de Pereira. Pereira, Colombia.
Email: caramirez@utp.edu.co

environment.
Results: The results obtained show that the proposed methodology is the most effective solution method for solving the problem, by achieving the greatest reduction in relation to the investment and operating costs. This methodology will allow the grid operators to identify the location and size of the D-STATCOMs within the electrical energy distribution system, with the lowest investment and operating costs in relation to other works reported in specialized literature.
Conclusions: The obtained results demonstrate that GA/PSO achieved the best performance, with the DCVSA comparison method in second place, and the GAMS solvers in third place. It is important to notice that it was not possible to evaluate the GAMS solvers on the 69 bus test system, because this solver failed the mathematical formulation that represented this electrical system. Based on previous results, it can be concluded that the GA/PSO is the most suitable optimization method used for solving the problem of optimal integration of D-STATCOMs in Distribution electrical systems for the grid.

Keywords: Distribution static compensator, electrical distribution planning, GAMS solvers application, metaheuristic optimization, optimal power flow, power loss minimization.

RESUMEN

Objetivo: El objetivo de este trabajo es proponer una metodología para la ubicación y dimensionamiento óptimo de D-STATCOM dentro de un sistema eléctrico de distribución, con el objetivo de reducir los costos operativos anualizados relacionados con las pérdidas anuales de energía eléctrica y los costos de inversión asociados con la instalación. del D-STATCOM.
Contexto: Este documento presenta una metodología híbrida basada en una estrategia maestro-esclavo entre los algoritmos genético y el de optimización de cúmulos de partículas para resolver el problema de localización y dimensionamiento de compensadores estáticos distribuidos (D-STATCOMs) para compensación reactiva en la red eléctrica de distribución.
Metodología: En este manuscrito fue empleado una formulación matemática que representa el efecto de la localización y dimensionamiento de compensadores D-STATCOMs en la red eléctrica de distribución; para lo cual se propone una estrategia maestro-esclavo entre los algoritmos genético y el de optimización de cúmulos de partículas como método de solución. Adicionalmente, con el objetivo principal de evaluar la efectividad y robustez del algoritmo fueron utilizados tres métodos de comparación, dos sistemas de prueba y múltiples consideraciones técnicas que representan las redes eléctricas de distribución de energía bajo un ambiente de recursos energéticos distribuidos.
Resultados: Los resultados obtenidos demostraron que la metodología de solución propuesta es la más efectiva de todos los métodos de solución empleados para resolver el problema aquí discutido. Logrando obtener la mayor reducción en los costos operativos del sistema con reducidos costos de inversión. Esta metodología permitirá a los operadores de red identificar la localización y dimensionamiento de los generadores dentro del sistema eléctrico de distribución de energía, con los menores costos de inversión en relación a otros trabajos reportados en la literatura especializada.
Conclusiones: Los resultados obtenidos demostraron que el GA/PSO alcanzó los mejores resultados, con el método DCVSA en el segundo lugar y los optimizadores de GAMS en tercero. Es importante notar que, en el sistema de 69 nodos no fue posible evaluar los optimizadores de GAMS, debido que estos fallan al solucionar el problema. Basado en los resultados anteriores, fue posible concluir que el GA/PSO es el método de optimización más adecuado para resolver el problema de localización y dimensionamiento de D-STATCOMs en redes eléctricas de distribución.

Palabras clave: Compensadores estáticos síncronos, planeamiento de sistemas eléctricos de distribución, aplicación de optimizadores GAMS, optimización metaheurística, flujo óptimo de potencia, reducción de pérdidas de potencia.

1 INTRODUCTION

In the last decades, with the development of the industrial society and the increase of population, it has been generated the need to improve the electrical distribution systems, in order to guarantee the quality and security of electrical services (Murray, W., Adonis, M., & Raji, A. (2021)), (Bahramara, S., Mazza, A., Chicco, G., Shafie-khah, M., & Catalão, J. (2020)), (Gil G., W., Montoya, O. D., Grisales-N., L. F., Ramírez V., C. A., & Molina C., A. (2020)). To carry out this task, in recent years different solution methodologies have been proposed which are based mainly on the integration of distributed energy resources for active and reactive compensation (Bahramara, S., Mazza, A., Chicco, G., Shafie-khah, M., & Catalão, J. (2020)), (Bouhouras, A. S., Sgouras, K. I., Gkaidatzis, P. A., & Labridis, D. P. (2016)). An example of this is the integration of distributed generators, capacitors, energy storage systems, and distribution static compensators among others (Mahmud, K., Khan, B., Ravishankar, J., Ahmadi, A., & Siano, P. (2020)), (Castillo, A. (2011)), (López, J. (2011)). Integrating these technologies on the grid is a revolutionary way to improve the technical and economic conditions of electrical distribution systems, and the focus of this research paper (Grisales-Noreña, L. F., Morales-Duran, J. C., Velez-Garcia, S., Montoya, O. D., & Gil-González, W. (2023)).

The optimal integration of D-STATCOMs in electrical grids has been widely studied in recent years. Due to the versatility and capacity of this kind of device, it has made reactive compensation and improved different technical and economic aspects to the grid: reduction of power losses, improve the voltage profiles, reduction of power flow on the lines, and operating costs among others (Montoya, O. D., Gil-González, W., & Hernández, J. (2021)). The positive impact of these devices on electrical networks is related to correct location and sizing, and this can only be achieved by using and adequate solution methodology (Eroğlu, F., Kurtoğlu, M., Eren, A., & Vural, A. M. (2023)), (Pedraza, A., & Reyes, D. (2015)). To obtain the major benefits through the integration of D-STATCOMs in the electrical grid, different works have been proposed in literature based on commercial software and metaheuristic optimization methods. An example of this is the works reported in (Montoya, O. D., Fuentes, J. E., Moya, F. D., Barrios, J. Á., & Chamorro, H. R. (2021)) where the solvers COUENNE and BONMIN of GAMS (General Algebraic Modeling System) were used, and a discrete version of the vortex search algorithm for reducing the annual operating and investment costs of a distribution

grid in an environment of D-STATCOMs. By using specialized software, the authors (Montoya, O. D., Alvarado-Barrios, L., & Hernández, J. C. (2021)) proposed an exact mixed-integer nonlinear programming model decoupled into two convex optimization sub-problems for reducing the investment and operational cost of electrical distribution systems through the integration of D-STATCOMs. This formulation allows the authors to obtain a mixed-integer quadratic programming model as a function of the active and reactive power flow. The modified mathematical formulation was solved by using the branch and bound method. The proposed methodology was validated in the test systems of 33 and 69 buses. This paper demonstrates that the implementation of new solution methodologies for solving the problem of optimal integration of D-STATCOMs in distribution electrical systems will improve the results obtained in economic terms. When comparing the results obtained with other methodologies reported in literature, (Tolabi, H. B., Ali, M. H., & Rizwan, M. (2014)) proposed a multi-objective particle swarm optimization algorithm for optimal integration of D-STACOMs by considering the electrical reconfiguration. In this paper, they used an objective function that improved of voltage profiles, the power losses reduction, and the branches load potential. The authors (Gupta, A. R., & Kumar, A. (2016)) proposed energy savings by employing D-STATCOM placement in a radial distribution system under a reconfigured network, using the index vector method for radial distribution networks with and without reconfiguration.

As with previous studies, various works have been reported in the literature to enhance the technical and economic indices of the electrical network, and demonstrate the importance and advantages of installing D-STATCOMs on the electrical grid. The location and operation of D-STATCOMs in distribution electrical grids of different sizes is addressed in (Montoya, O. D., Alvarado-Barrios, L., & Hernández, J. C. (2021)). In this case, a MNLP model was used to present the problem with the aim of minimizing the annual operating costs of the grid by including the investment costs. By considering the behavior of different load profiles: residential, industrial, and commercial; a variable energy demand scenario was utilized. For solving the mathematical formulation, the authors used the software GAMS by considering a mono and multi-objective analysis. The simulations demonstrated that the location and operation of the compensator reactive power devices in the electrical systems improved the operational costs. (Belhamidi, M., Lakdja, F., Guentri, H., Boumediene, L., & Yahiaoui, M. (2023)) evaluated the impact of integrated and operated DSTATCOM of different sizes in an electri-

cal network with the operation of wind turbines and variable power demand. The simulations were carried out by using the toll Simulink of MATLAB and demonstrated that the correct operation of D-STATCOMs on the grid improved the technical conditions of the grid. In (V., V. R. R., Doddi, B., Dixit, S., & B., L. (2023)) a multilevel control for operating D-STATCOMs in an electrical grid was proposed, based on closed loop controller, which allowed for improved technical conditions of the grid under a scenario of power variations. The simulation results were then compared with other control methodologies proposed in literature and demonstrated the robustness and flexibility of the proposed control strategy. (Akkad, A. F., Erdili, N., & Sosnina, E. (2023)) proposed a methodology based on a fuzzy logic controller by operating a D-STATCOM in an electrical grid with the aim to improve the effectiveness of this kind of technology in the technical parameters of the grid. (Ulloa de Souza, A. G. (2018)) proposed a mathematical optimization model by using MNLP solved with GAMS for the optimal location and sizing of the D-STATCOMs in distributed electrical systems. His ultimate aim was to improve the technical conditions of the grid. As test scenarios, it used the test systems of 33 and 69 buses and considered an objective function that reduced active power losses and improved the voltage profile by considering all operating restrictions of the grid.

By recognizing the importance of the problem of optimal integration and operation of D-STACOMs in electrical distribution systems, the aim of this work was to propose an efficient and robust solution methodology for this problem. In this paper, a master-slave methodology in combination with the genetic and particle swarm optimization algorithm was proposed. By using as objective function the reduction of the annual operating cost associated to the energy power losses and investment costs. Three comparison methodologies and two test systems were used to evaluate the effectiveness of the solution and methodology proposed. The obtained results demonstrate that the proposed methodology achieved the best solution. It was observed that as the size of electrical distribution systems increases, the proposed methodology outperforms the comparison methods.

As main contribution of this paper, it is important to mention the implementation of a new master-slave methodology based on the genetic algorithm and the particle swarm optimization method that allowed the improve results for solving the problem of optimal integration of D-STATCOMs and thus reducing the investment and operational costs.

Mathematical Formulation

The mathematical formulation used for optimal location and sizing of D-STATCOMs in electrical systems is presented in Equations (1) to (8). This mathematical formulation describes a non-linear and non-convex problem (Montoya, O. D., Alvarado-Barrios, L., & Hernández, J. C. (2021)), which is composed by a pondered multi-objective function with the same weight for both functions: 1, and a set of constraints describe the operation of electrical distribution system under a distributed generation environment. The entire mathematical formulation is described below.

Objective function:

$$minA_{cost} = f_1 + f_2 \tag{1}$$

The objective function in this paper used the reduction of the annual operative costs (A_{cost}) related to the annual power energy losses (f_1) and the investment costs associated to the installation of the D-STATCOM in electrical grid (f_2), see Equation (1).

$$f_1 = C_{kWh} T \sum_{h\in\mathcal{H}} \sum_{i\in\mathcal{N}} \sum_{j\in\mathcal{N}} Y_{ij} V_{ih} V_{jh} \text{coscos}\left(\delta_{ih} - \delta_{jh} - \theta_{ij}\right) \Delta_h \tag{2}$$

Equation (2) describes the annual power losses costs attributed to a year of operation (f_1), this equation considered the hourly behavior of the electrical system; where H and N are the sets that contain all the periods of times analyzed and the nodal buses that compose the electrical grid, respectively. In this equation C_{kWh} corresponds to the energy cost per kWh, T is a constant that allows for evaluating the horizon time used (1 year). Y_{ij} and δ_{ij} represent the magnitude and angle of the nodal admittance matrix associated with the nodes i and j. V_{ih} and V_{jh} represent the magnitudes of the voltage in the nodes i and j at the hour h, respectively; the variables δ_{ih} and δ_{jh} represents the voltage angle for the same buses at the same period. Finally, Δ_h is the time associated with the power flow analysis, 1/2 hour for this case (the power demand change in steps of 0.5 hours, see figure (4)).

$$f_2 = T\left(\frac{k_1}{k_2}\right) \sum_{k\in\mathcal{N}} \left(\alpha\left(\mathcal{Q}_k^{D-STATCOM}\right)^2 + \beta\mathcal{Q}_k^{D-STATCOM} + \gamma\right) \mathcal{Q}_k^{D-STATCOM} \tag{3}$$

Furthermore, the Equation (3) represents the annual investment cost associated to the location of D-STATCOMs in electrical systems. In this equation, k_1 and k_2 are constants used for the annualization of the operating cost and useful life, respectively. α, β and γ are the constant that compose the mathematical model used to obtain the variable investment cost attributed to location of D-STATCOMs on the electrical grid, which is a function of the reactive power selected for each $D-STATCOM$ ($Q_k^{D-STATCOM}$).

Set of constraints:

The set of constraints that compose the mathematical formulation discussed here is presented from Equations (4) to (8).

$$P_{ih}^{g} - P_{ih}^{d} = \sum_{i\in\mathcal{N}} \sum_{j\in\mathcal{N}} Y_{ij} V_{ih} V_{jh} \cos\left(\delta_{ih} - \delta_{jh} - \theta_{ij}\right) \tag{4}$$

$$\mathcal{Q}_{ih}^{g} + \mathcal{Q}_{i}^{D-STATCOM} - \mathcal{Q}_{ih}^{d} = \sum_{i\in\mathcal{N}} \sum_{i\in\mathcal{N}} Y_{ii} V_{ih} V_{ih} \sin\left(\delta_{ih} - \delta_{ih} - \theta_{ii}\right) \tag{5}$$

$$V_{min} \leq V_{ih} \leq V_{max} \tag{6}$$

$$x_i \mathcal{Q}_{min}^{D-STATCOM} \leq \mathcal{Q}_{i}^{D-STATCOM} \leq x_i \mathcal{Q}_{max}^{D-STATCOM} \tag{7}$$

$$\sum_{i\in\mathcal{N}} x_i \leq N_{available}^{D-STATCOM} \tag{8}$$

Equation (4) and (5) represent the nodal active and reactive power balance, where P_{ih}^{g} and Q_{ih}^{g} correspond to the active and reactive power generated in the bus i on the period h; P_{ih}^{d} and Q_{ih}^{d} denote the active and reactive power demanded in the same bus and period. In Equations aforementioned, $Q_{ih}^{D-STATCOM}$ correspond to the reactive power injected by the D-STATCOM in the bus i on the period h. Equation (6) represent the voltage nodal bounds, where V_{min} and V_{max} are the minimum and maximum bus voltage allowed. The maximum $Q_{max}^{D-STATCOM}$ and minimum $Q_{min}^{D-STATCOM}$ reactive power limits are fixed for the $D-STATCOM$ located on the bus i are presented in Equation (7). Where x_i is a binary variable that takes a value of 1 if a $D-STATCOM$ is located on bus and 0 if not. Finally, Equation (8) limits the maximum number of $D-STATCOMs$ that are allowed to be installed on the distribution system.

Table (1) describes the parameters used for evaluating the mathematical formulation described in the last paragraph.

Table 1. Parameters used in the mathematical formulation.

Source: Authors.

Parameter	Value	Unit	Parameter	Value	Unit
C_{kWh}	0.1309	US$/kWh	T	365	Days
Δ_h	0.50	h	α	0.30	US$/MWh^3
β	-305.10	US$/MWh^2	γ	127380	US$/MWh
k_1	6/2190	1/Days	k_2	10	Years

Master-Slave methodology: GA/PSO

For solving the problem of optimal location and sizing of $D-STATCOMs$ in distribution electrical systems, in this paper a master-slave methodology was used with a combination of the Genetic Algorithm of Chu & and Beasley (GA) and the Particle Swarm Optimization algorithm (PSO). In master slave the GA is entrusted to solve the location problem and in the slave stage the PSO solves the sizing problem for each possible solution proposed by the master stage. The proposed methodology is described and explained below.

Master stage: Genetic Algorithm (GA)

In the master-slave methodology proposed implemented the GA in the master stage. This optimization method using an initial population generated through an aleatory process, which was combined with the generation of new decedents (created using the criterion of selection, recombination, and mutation), with the aim to obtain the optimal location of the $D-STATCOM$ inside the distribution electrical system.

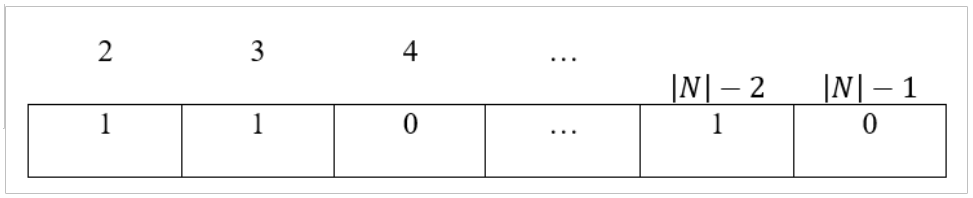

Figure 1. Binary codification for D-STATCOM location problem.

Source: Authors.

Figure (1) presents the codification used for solving the location problem, this codification is composed by a vector of $1 \times N-1$, where $N-1$ corresponds to the number of nodes that compose the distribution system, without considering the slack bus. By assigning a value of 1 when a $D-STATCOM$ is located on the bus and 0 if not.

Algorithm 1 Pseudo-code proposed for GA used in master slave

Data: Read data of electrical grid and GA parameters.
for $t = 1$: number of generational cycles **do**
if t==1 **then**
Generate the initial population;
Evaluate the objective function and constrains for each individual by using the slave stage (Sizing problem);
Select the best solution of the population as incumbent;
else
Generate an descendent by using selection, recombination and mutation;
Evaluate the objective function and constrains for descendent by using the slave stage (Sizing problem);
Replace the worst individual of the population with the descendent if the descendent improve its objective function;
Update the incumbent.
if the stopping criterion has been met **then**
Finish the optimization process;
Solution found;
Print results;
Break;
else Continue;
end if
end if
end for

The pseudo-code that represents the optimization process of the GA used in the master stage is described in Algorithm (1). In this algorithm, it can be appreciated that the first iteration generates the initial population through an aleatory process. Then, the objective functions and constraints of all individuals in the population are evaluated by using the slave stage, which is entrusted to the sizing of each D-STATCOM located on the electrical system. Subsequently, it selects the best solution of the problem with the individual with the minor value of annual cost (incumbent).

From the second iteration until the completion of the iterative process of the GA, each iteration generated a new descendant through of the selection of individuals of the current population as parents (four in this particular case), which are recombined and mutated for generating the t descendant. Then, it is evaluated the objective function and constraints related to this descendant by using the slave stage. After this, if and only if, the objective function obtained for the descendant improves the objective function of the worst parent, the descendant would replace this inside the population. Subsequently, it would be update the incumbent of the problem. Finally, it was verified that the stopping criterion would be achieved when the maximum number of generational cycles and the maximum iteration number was completed without improvement.

Slave stage: Particle swarm optimization method (PS)

2	3	4	…	$\|N\|-2$	$\|N\|-1$
1,5	0,12	0	…	0,3	0

Figure 2. Continuous codification for D-STATCOM sizing problem.

Source: Authors.

The slave stage is responsible for sizing the $D-STATCOMs$ located in each configuration proposed by master stage. To carry out this task, a vector codification was used with continuous variables, see Figure (2). In this figure, it can be appreciated that in an example mode, for buses 2,4 and N-2 were assigned values of reactive power between the minimum and maximum values allowed by $D-STATCOMs$ located in such buses.

Algorithm 2 Pseudo-code for the PSO algorithm

Data: Read electrical systema data and PSO parameters.
for $t = 1 : tmax$ **do**
if t==1 **then**
Generate the particles swarm in a randomly;
Evaluate the objective function and constrains for each particle by using the hourly power flow method based on SA;
Select as best particle solution and position the solution and position presented by each particle;
Select as best swarm solution and position the best solution presented by the swarm particles and its position associated;
else
Calculate the velocity vector;
Update the position of the particles swarm;
Evaluate the objective function and constrains for each particle by using the hourly power flow method based on SA;
Update best particle and swarm solution and position;
if the stopping criterion has been met **then**
Solution found;
Finish optimization process;
Return the sizing values for D-STATCOMs to the master slave;
Break;
else Continue;
end if
end if
end for

Algorithm (2) presented the iteration process related to the PSO algorithm used for solving the sizing problem. In this algorithm, it can be observed that the first iteration generated the particles swarm

in an aleatory way. This first population corresponding to the sizing of D-STATCOMs proposed for a location configuration assigned by the master slave. Then, it is evaluated the objective function and constraints for each particle of the swarm. This is possible solving the power flow problem through an hourly power flow SA method (explained in the next subsection of this document), by using an objective function to reduce the annual cost that it is evaluated in each operation period. Then in the first iteration, it assigned the objective function and position for each particle as the best solution and position achieved by each particle. Subsequently, the best solution found inside the swarm and the position associated to this solution, it is selected as incumbent of the sizing problem.

The second iteration until the last, for each iteration, is calculated by a velocity vector which is responsible for updating the position of the particles in the solution space (Grisales-Noreña, L. F., Gonzalez, D., & Ramos-Paja, C. A. (2018)), (Grisales-Noreña, L. F., Montoya, O., & Ramos-Paja, C. A. (2020)). Then, the new position of the swarm is evaluated with the objective function and constraints for each particle using the hourly power flow method based on successive approximations. Updating the best solution and position of each particle in each iteration continues if the solution achieved in the current iteration improves the solution of the last. Afterwards, it has updated the incumbent of the sizing problem. Finally, the iteration process finishes if the stopping criterion has been met, in other case this continues. For this paper, the PSO used a stopping criterion of the maximum number of iteration and a maximum number of iterations without improvement. Finally, the slave stage returns the best solution found to the master stage when the iterative process finished. This solution corresponding to the sizing of D-STATCOMs located for each individual proposed for the master stage.

Hourly power flow bases on Successive Approximation method (SA)

In each iteration of the proposed methodology, it generates a population of individuals related to different solutions for the problem studied in this paper. Each individual proposed for the master-slave must be evaluated for obtaining its effect in the objective function of the problem, as well as to validate and satisfy all sets of constraints that describe the operation of a distribution electrical system in a scenario of D-STATCOM operation and variable power demand. To carry out this labor, an hourly version of the successive approximation method reported in (Grisales-Noreña, L. F., Montoya,

O. D., Cortés-Caicedo, B., Zishan, F., & Rosero-García, J. (2023)) and (Montoya, O. D., Garrido, V. M., Gil-Gonzalez, W., & Grisales-Norena, L. F. (2019a)), (Montoya, O. D., Garrido, V. M., Gil-Gonzalez, W., & Grisales-Norena, L. F. (2019b)) was used. The algorithm (3) that represents the iteration process of the used hourly power flow method is presented and described below:

Algorithm 3 Pseudo-code for the hourly power flow method based on SA

Data: Read electrical systema data location and power dispatch proposed for the D-STATCOM.

for $t = 1 : 48$ **do**

Load the power demand for the hour t;

Load the location and power dispatch of reactive power for the D-STATCOMs for the hour t;

Solve the power flow for the hour h using the SA (Montoya et al., 2019b);

Calculate the operation cost for the hour h;

Calculate the set of constraints for the hour h;

end for

Calculate f_1,f_2 and A_{cost}

Return the A_{cost} to the -slave stage;

The hourly power flow used in this paper, in the first step, is loading the power demand for the hour t of the loads connected to the electrical distribution system. Then, the hourly power flow loads the location and power dispatch of reactive power for the D-STATCOMs for the same hour. Subsequently, by using the SA reported in (Montoya, O. D., Garrido, V. M., Gil-Gonzalez, W., & Grisales-Norena, L. F. (2019b)), it calculated the operational costs and the set of constraints that formulated the problem for the hour t. This process continued until all hours that compose the horizon time were analyzed, in this case 24 hours, represented in 48 steps of 0.5 hours. Finally, by considering the operation and investment cost, it calculated the A_{cost}; by returning the objective function value to the master-salve methodology.

Test Systems, Comparison Methods and Test Scenarios

To verify the effectiveness of the master-slave methodology proposed this paper, the test systems of 33 and 69 buses were used. Solving the problem of optimal integration of distributed resources has been implemented as reported in specialized literature (Grisales-Noreña, L. F., Gonzalez, D., &

Ramos-Paja, C. A. (2018)), (Moradi, M. H., & Abedini, M. (2012)) It is described in the next subsections.

It is important to highlight that the average time of the solution for methodologies was 38 minutes. This is a negligible time in relation to the time considered within the planning horizon time (years). Therefore, the authors of this manuscript did not consider adequately to carry out an analysis of the processing times required by the solution methodologies here analyzed.

33 nodes test system

This electrical test system is composed of 33 nodes, 32 branches, multiple constant power loads and a unique slack generator. Figure (3)(a) presents the electrical diagram and its technical information is explained in (Grisales-Noreña, L. F., Gonzalez, D., & Ramos-Paja, C. A. (2018)).

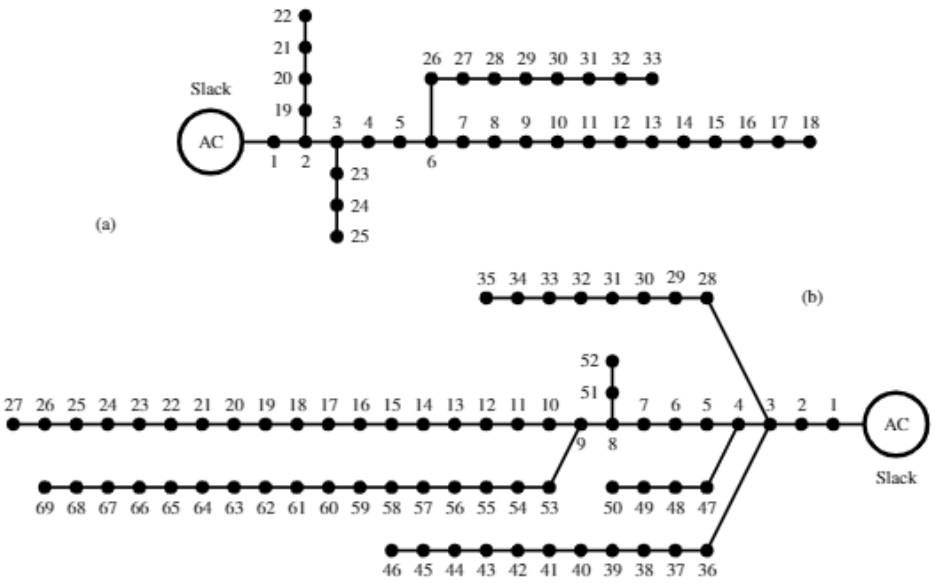

Figure 3. Electrical configuration of test systems used (a) 33 nodes test systems, and (b) 69 nodes test system., (Montoya, O. D., Gil-González, W., & Hernández, J. (2021)).

Source: Authors.

69 bus test system

The electrical configuration of this test system is presented in Figure (3)(b). This system is composed of a unique slack generator, 33 buses, 69 branches and different power constant loads localized in the different buses of the system. Base values were employed with 12,66 kV and 100 kVA, respectively. All technical parameters of this test system are described in (Grisales-Noreña, L. F., Gonzalez, D., & Ramos-Paja, C. A. (2018)).

Comparison methods, test scenarios and considerations

Comparison methods, test scenarios and considerations: Comparison methods in this paper were used which include two solvers of the specialized software General Algebraic modeling System (GAMS): BONMIN and COUENNE solvers, and the discrete version of the vortex search algorithm (DCVSA) (Montoya, O. D., Gil-González, W., & Hernández, J. (2021)) which used the tuning parameters proposed by the authors. For the proposed GA/PSO, the parameters were tuned by using a PSO algorithm obtained from the values reported in Table (2).

Table 2. Parameters of master–slave methodology proposed.

Source: Authors.

Method	**GA**	**PSO**
Numbers of particles	12	30
Selection method	Tournament	Cognitive and social component: 1,4
Update population method	Cross over: simple	Speed (max-min): (0,1 – 0,1) Inertia (max-min): (0,7 – 0,001)
Mutation	Binary simple	R1=R2: Random
Stopping criterion	Gerational cycles: (200) Iteration without improve: (50)	Maximum iterations: (200) Iteration without improve: (50)

In addition, it is used a maximum number of three D-STATCOMs to be located in the distribution system by considering all buses of the electrical grid as candidates for location, except the Slack bus.

Furthermore, as reactive power bounds were considered, a minimum and maximum value of 0 MVAr and 2 MVAr were used, respectively. Finally, due to the mathematical formulation proposed in this paper, the hourly variation of active and reactive power demand on the electric systems in periods of 0,5 hours for a day of operation were selected (48 periods), see Figure (4). This figure illustrated the typical behavior in power demand of a electrical distribution systems of Colombia (Montoya, O. D., & Gil-Gonzalez, W. (2020)), used for both test systems.

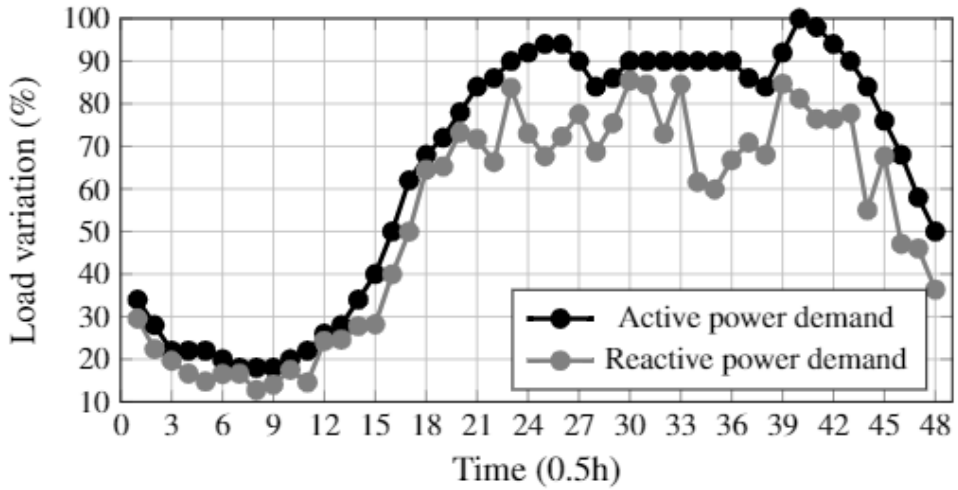

Figure 4. Typical behavior of the active and reactive power consumption in a Colombian electrical distribution system. (Montoya, O. D., Alvarado-Barrios, L., & Hernández, J. C. (2021)), (Montoya, O. D., & Gil-Gonzalez, W. (2020)).

Source: Authors.

Simulation Results

To run all simulations, this paper used the software GAMS for commercial solvers and the Matlab software for the solution methods based on sequential programming. The software ran on a PC with an AMD Ryzen7 3700 2,3 GHz processor and 16,0 GB RAM, running on a 64 bits version of Microsoft Windows 10. In the next subsection the results were analyzed for each test system:

33 nodes test system

Table (3) presents the results obtained for the different solution methods for solving the problem of optimal integration of D-STATCOMs in electrical distribution systems. This table showsleft to right the following information: the solution method used, the location and size in MVAr of the different D-STATCOMs on electrical system, and the annual cost related to the integration of these devices in US$ per year.

Table 3. Results obtained for 33 nodes sytems.

Source: Authors.

Method	**Location (Size node (MVar))**	A_{cost} **(US$/year)**
Base case	-	112740,90
COUENNE	$\{16\,(0,0109)\,,\ 17\,(0,0224)\,,\ 18\,(0,2065)\}$	107589,50
BONMIN	$\{17\,(0,0339)\,,\ 18\,(0,0227)\,,\ 30\,(0,2395)\}$	102447,29
DCVSA	$\{14\,(0,1599)\,,\ 30\,(0,3591)\,,\ 32\,(0,1072)\}$	98497,90
GA/PSO	$\{14\,(0,1599)\,,\ 30\,(0,3497)\,,\ 31\,(0,1166)\}$	98511,63

The Figure (5) presents the reduction obtained by the different solution methods with respect to the base case. In this figure, it can be appreciated that all solution methods reduce the annual costs, by obtaining a reduction of 4,56 % (COUENNE), 9,13 % (BONMIN), 12,63 % (DCVSA) and 12,62 % (GA/PSO) in relation to the base case. By analyzing these results, it can be appreciated that the proposed methodology created the second greatest savings with an annual cost of $98511,63US/year$, surpassed only by DCVSA by 0,01 %. With respect to the GAMS solvers, the GA/PSO reduced the annual cost by 8,05 % and 3,49 %, respectively.

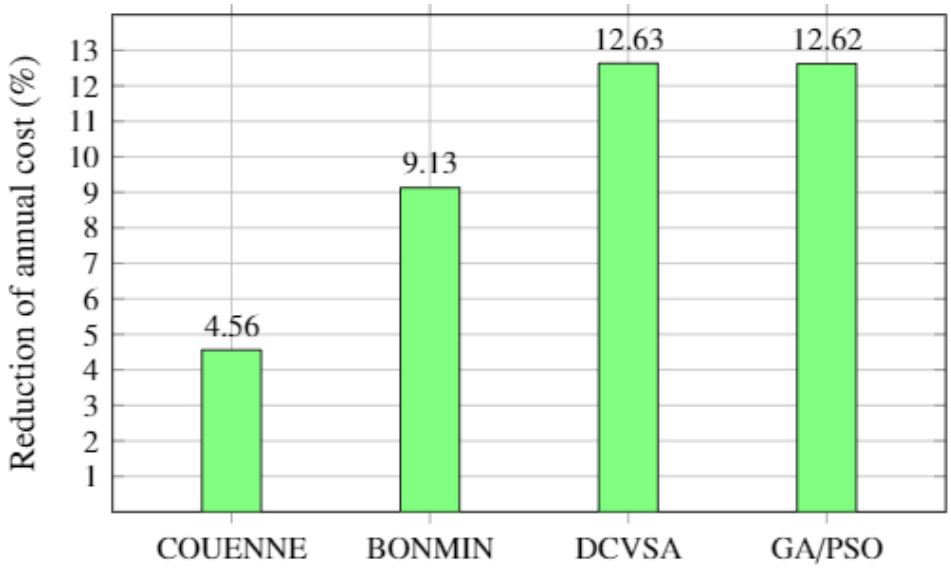

Figure 5. Reduction obtained in annual cost by the solution methods in 33 nodes test systems with respect to the base case.

Source: Authors.

The operational and investment costs provided by each solution and the base case is presented the Figure (6), where is possible to identify that greater investments were made by the DCVSA and GA/PSO corresponding to $7,97{\cdot}10^3$ US$. Furthermore, due to the greater investment in D-STATCOM devices which lower operational costs to $90,53 \cdot 10^3 US\$$ (DCVSA) and $9,54 \cdot 10^3 US\$$ (GA/PSO). By observing these results, it is possible to notice that the GA/PSO is just 0,01 % lower than the best solution (DCVSA) while maintaining an average reduction of 4,54 % with respect to the other methodologies.

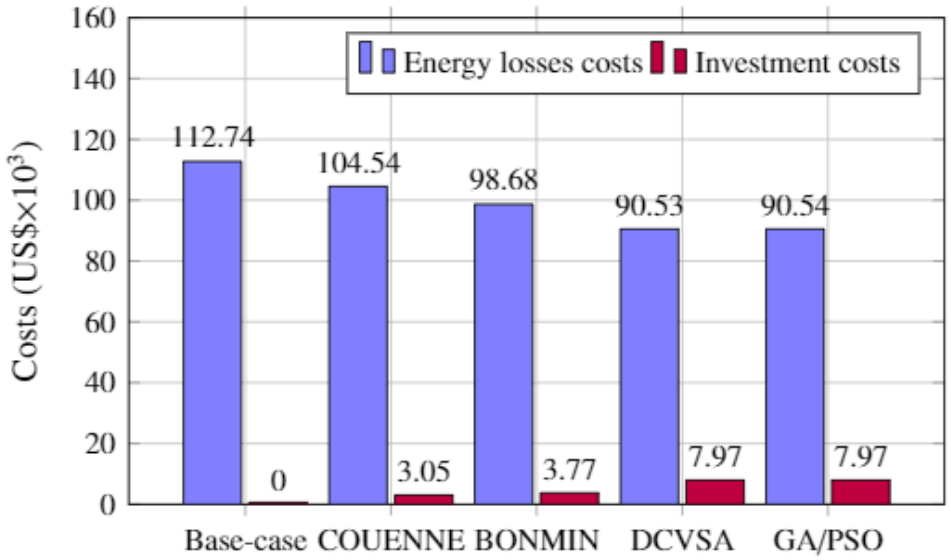

Figure 6. Comparison of the operative and investment costs for 33 bus.

Source: Authors.

69 nodes test system

For this test system, it was not possible to obtain the results for the GAMS solvers, since both solvers failed to solve the mathematical formulation for the 69 nodes test systems. This shows the effectiveness and robustness of the solution methods based on sequential programming of the proposed methodology. In this way, Table (4) presents the results obtained by the DCVSA and GA/PSO for 69 nodes test systems.

Table 4. Results obtained for 69 nodes systems.

Source: Authors.

Method	**Location (Size node (MVar))**	A_{cost} **(US$/year)**
Base case	-	119715,63
DCVSA	$\{21\,(0,0839)\,,\ 61\,(0,4601)\,,\ 64\,(0,1139)\}$	102990,80
GA/PSO	$\{21\,(0,0839)\,,\ 61\,(0,4600)\,,\ 64\,(0,1139)\}$	102990.79

In the last table (4), it was possible to observe that both solution methods select the same nodes

for located the D-STATCOMs in distribution electrical system, and the fixed size for each device are similar by providing an average reduction of the annual costs in both solutions of 13,97 %, see Figure (7).

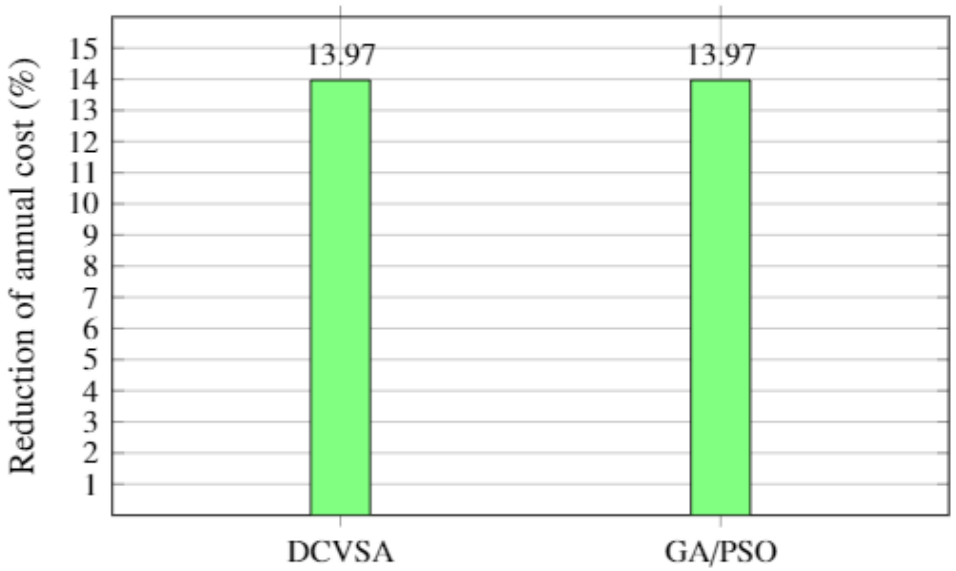

Figure 7. Reduction obtained in annual cost by the solution methods DCVSA and GA/PSO in 69 nodes test systems with respect to the base case.

Source: Authors.

Figure (8) illustrated the operational and investment costs for both solution methodologies by achieving in both cases a value of $94,61 \cdot 10^3 US\$$ and $8,37 \cdot 10^3 US\$$, respectively.

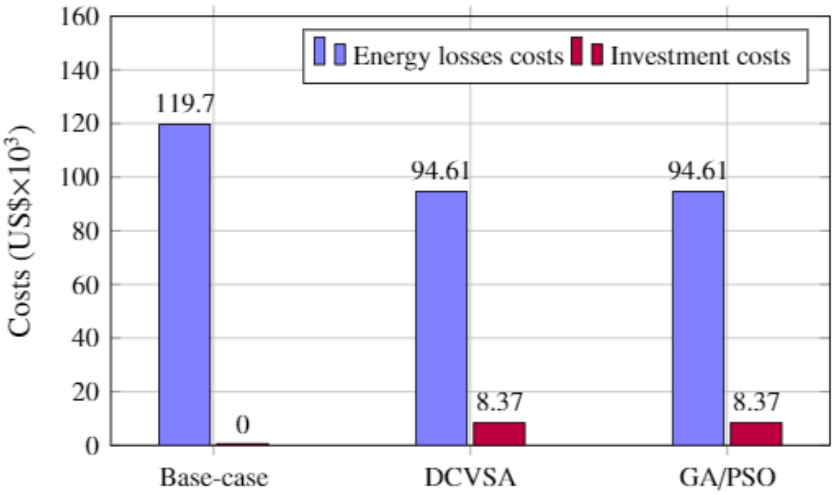

Figure 8. Comparison of the operational and investment costs for 33 bus

Source: Authors.

However, a closer look at results reported in Table (3) reveals that the GA/PSO was the solution methodologies that reported the best solution, by providing a reduction of the annual operating cost of $8,3510^{-6}$ % with respect to the DCVSA. This is a lower difference, but this value demonstrates that the proposed methodology improved the results reported in specialized literature for solving the problem studied. It should be recognized that the solver of GAMS failed to solve the problem when the solution space increased in size.

2 Conclusions

In this paper, it was proposed a master-slave methodology combined with the GA and PSO algorithms, with the aim to reduce the annual cost, operating and investment cost associated with active power losses and installation costs of D-STATCOMs, of an electrical distribution system by means of the optimal location and sizing of D-STATCOMs devices on the grid, by considering the variation in the power demand in a horizon time of 24 hours. For evaluating the effectiveness and robustness of the GA/PSO methodology, in this paper two electrical test systems of 33 and 69 nodes and three comparison methodologies based on commercial software and sequential programming were used. By analyzing the results obtained by the different solution methodologies in the small electrical sys-

tem (33 bus test system), it was possible to observe that the GA/PSO presented the best results when compared with the commercial solvers of Matlab (COUENNE and BONMIn). Furthermore, the GA/PSO was second only to DCVSA with only a difference 0.01% with respect to the reduction of annual costs. For this reason, the proposed methodology is considered an adequate solution methodology for solving the problem of optimal integration of D-STATCOMs in small electrical distribution systems.

With the aim to verify the robustness of the different methodologies used in larger test systems, the 69 nodes test system was used. The results obtained demonstrated that the GA/PSO obtained the best results, with the DCVSA in second place. It is important to notice that it was not possible to evaluate the Matlab solvers on 69 bus test system, due to this solver failing the mathematical formulation that represented this electrical system. Based on the previous results, it is possible to conclude that the GA/PSO is the most suitable optimization method used for solving the problem of optimal integration of D-STATCOMs in distribution electrical systems for large size grid.

The location and sizing of D-STACOMs in electrical networks is a non-convex problem, due to the presence of binary variables associated with the location, and the nonlinearities existing within the global power balance constraint, which is the base of the power flow problem, necessary to evaluate the effect of each location and sizing of the D-STATCOMs within the network. MATLAB's solvers work well with continuous variable problems, guaranteeing the global optimum every time that these are executed. This occurs when this kind of optimization methods solve the power dispatch problem of distributed energy resources. However, when adding the problem of location to these technologies within the network, the nonlinearities associated with the binary variables means that the GAMS solvers are trapped in local optima. Based on the above, it is possible to conclude that the integration of binary variables into the mathematical model generates GAMS solvers that are not as efficient as metaheuristic optimization algorithms based on sequential programming such as GA/PSO.

In future work, it should be considered that the implementation of new solution methodologies that allow for improved results be reported in the literature, as well as by including other distributed energy resources inside the electrical grid as distributed generators and energy storage devices, with the aim to improve the technical and economic conditions of the grid.

Financing:

This article was financed by the Universidad de Talca, Universidad Tecnológica de Pereira, and the Universidad del Valle.

Gratitude:

The authors would like to thank Universidad de Talca, Universidad Tecnológica de Pereira, and the Universidad del Valle.

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https://revistas.udistrital.edu.co/index.php/Tecnura/issue/view/1201
DOI: https://doi.org/10.14483/22487638.19197

INVESTIGACIÓN

Cooperative strategy to reduce path length in risky environments

Estrategia cooperativa para reducir la longitud de la ruta en entornos riesgosos

José Andrés Chaves Osorio [1], Jimy Alexander Cortés Osorio [2], Edward Andrés González Ríos [3]

Fecha de Recepción: 14 de marzo de 2022 **Fecha de Aceptación**: 12 de diciembre de 2022

Cómo citar: Chaves-Osorio, J.A., Cortés-Osorio, J.A., González-Ríos, E.A. (2023). Cooperative strategy to reduce path length in risky environments. *Tecnura*, **27**(78), 42-72. https://doi.org/10.14483/22487638.19197

ABSTRACT

Objective: Design an artificial intelligence system based on information from the environment that can recommend the shortest path to an individual or vehicle, or robot that moves between two points with the lowest risk of contagion with coronavirus COVID-19.

Methodology: The cooperative strategy for path reduction involves a management and monitoring system and two explorer agents. Explorer agents are equipped with path planning algorithms (GBFS and A*) enhanced with incremental heuristics in order to find two different sets of preliminary paths (the first in direction start-goal and the second in the opposite direction). Subsequently, a management and monitoring system estimates a preliminary shortest path for each path planner then obtains a shortest path by comparing the paths attained with the path planners. This research emerges within the field of distributed intelligence in robotics to determine the benefits of teamwork interactions compared to individual work. In this study, 300 tests that involve the cooperative strategy were executed using ten different environments.

Results: The results of this paper illustrate that in 79% of analyzed situations, definitive shortest estimated paths obtained by cooperative strategy outperformed preliminary paths found individually by path planners. Over 20.5% of tested cases yielded significant path reductions (greater than 100% in relation to the shortest definitive path).

Conclusions: In this work, an artificial intelligence system was designed, whose tests show a good performance. The intelligent system uses Distributed Intelligence implemented in a cooperative team formed by a management and monitoring

[1]PhD in Engineering, Magister in Physical instrumentation, Electrical engineer. Professor in Basic Sciences and Engineering Faculties, Co-Director of research group Robótica Aplicada. Faculty of Basic Sciences, Universidad Tecnológica de Pereira. Pereira, Risaralda, Colombia.
Email: jachaves@ utp.edu.co
[2]PhD in Engineering, electrical engineer. Professor in Physics department, Director of research group Robótica Aplicada. Faculty of Basic Sciences, Universidad Tecnológica de Pereira. Pereira, Risaralda, Colombia.
Email: jacoper@utp.edu.co
[3]Magister in Physical instrumentation, Electronics engineer. Professor in Mechatronic Engineering, researcher in the research group Robótica Aplicada. Faculty of Basic Sciences. Pereira, Risaralda, Colombia.
Email: edangonzalez@utp.edu.co

system and two explorer agents, who, based on information from the environment, recommend the shortest path to an individual or vehicle or robot who wants to travel between two points located in an environment at risk of contagion with coronavirus COVID-19.
Financing: This work was supported in part by the Universidad Tecnológica de Pereira through Vicerrectoría de Investigaciones Innovación y Extensión, Project name: Sistema de obtención de rutas más seguras bajo situación de pandemia caso covid-19, Project code: 3-20-11, and in part by the Universidad nacional de Colombia.

Keywords: Agent-based modeling, autonomous robots, collaborative work, collision avoidance, cooperative systems, multi-agent systems, navigation, path planning.

RESUMEN

Objetivo: Diseñar un sistema de inteligencia artificial que con base a información del entorno pueda recomendar la ruta más corta a un individuo que quiera desplazarse entre dos puntos con el menor riesgo de contagio con coronavirus COVID-19.
Metodología: La estrategia cooperativa para la reducción de rutas involucra un sistema de administración y monitoreo y dos agentes exploradores. Los agentes exploradores están equipados con algoritmos de planificación de rutas (GBFS y A*) mejorados con heurísticas de tipo incremental a fin de encontrar dos conjuntos diferentes de rutas preliminares (la primera en dirección inicio-meta y la segunda en dirección opuesta). Posteriormente, el sistema de administración y monitoreo estima de forma preliminar el camino más corto para cada planificador de rutas y luego se obtiene el camino más corto comparando los caminos obtenidos con cada uno de los planificadores de rutas. Esta investigación surge dentro del campo de la inteligencia distribuida en robótica para determinar los beneficios de las interacciones del trabajo en equipo frente al trabajo individual. En este estudio se ejecutaron 300 pruebas que involucran la estrategia cooperativa utilizando diez ambientes diferentes.
Resultados: Los resultados de este artículo ilustran que en el 79% de las situaciones analizadas, las rutas estimadas más cortas obtenidas por la estrategia cooperativa fueron aún más cortas que las rutas preliminares encontradas individualmente por los planificadores de rutas. Adicionalmente, en más del 20,5 % de las pruebas realizadas se obtuvieron reducciones de ruta significativas (superiores al 100 % en relación con la ruta más corta).
Conclusiones: En este trabajo se diseñó un sistema de inteligencia artificial, cuyas pruebas muestran un buen desempeño. El sistema inteligente utiliza Inteligencia Distribuida implementada en un equipo cooperativo formado por un sistema de administración y monitoreo y dos agentes exploradores, los cuales, con base a información del entorno, recomiendan el camino más corto a un individuo o vehículo o robot que quiera desplazarse entre dos puntos ubicados en un entorno con riesgo de contagio de coronavirus COVID-19.
Financiamiento: Este trabajo es financiado en parte por la Universidad Tecnológica de Pereira a través del VIIE, Nombre del proyecto: sistema de obtención de rutas más seguras bajo situación de pandemia caso covid-19, Código del proyecto: 3-20-11 y en parte por la Universidad Nacional de Colombia.

Palabras clave: Modelado basado en agentes, robots autónomos, trabajo colaborativo, evasión de colisiones, sistemas cooperativos, sistemas multiagente, navegación, planificación de rutas.

1 INTRODUCTION

Currently, humanity is being subjected to a health emergency of enormous proportions due to the SARS-CoV2 coronavirus pandemic and the associated disease COVID-19 (Islam & Islam, 2020); (Jamshidi *et al.*, 2020). According to the information given by the World Health Organization (WHO), as of 6 March 2022, over 433 million confirmed cases and over 5.9 million deaths had been reported globally. After a couple of years in quarantine and due to significant economic and social needs, there is a glimpse of the possibility that governments allow citizens to leave their homes under specific security protocols. Therefore, it is essential to take advantage of the outbreak places information, as zones with the highest number of infected to evaluate the risk of contagion based on these data. The robotics has been relevance in the context of COVID, as presented by (20) Vargas-Pard et al. (2022), in their work about review of the robotics in the context of COVID healthcare. Their work explores various aspects, such as robotic assistance in patient care, disinfection and cleaning tasks, telemedicine, and remote monitoring. The review highlights the advantages of robotics, including reduced human contact, enhanced efficiency, and improved safety for healthcare workers. The authors conclude that robotics plays a crucial role in mitigating the impact of the pandemic by providing innovative solutions in healthcare delivery.

(Becerra-Mora & Arbulu-Saavedra, 2022) presents an Algorithm for Facility Layout Optimization that is significant in route planning by minimizing distances and flow times in the production chain. Although not explicitly designed for COVID-19, this optimization method holds the potential for managing the pandemic by efficiently organizing resource and equipment distribution in healthcare facilities. The study highlights the importance of researching this topic and the potential contributions various works in route planning can make.

(Martínez-Valencia *et al.*, 2021) presented a methodology for motion planning in autonomous systems with multiple agents; even though it was not aiming to contribute to COVID-19 route planning and mitigation strategies, it could alternatively contribute to covid mitigation in terms of route planning. The proposed methodology parameterized the physical behavior of autonomous navigation systems and implements a control policies algorithm. The methodology proposed in their paper showcases its effectiveness in motion planning for autonomous systems with multiple agents. This

methodology can enhance the efficiency and effectiveness of COVID-19 route planning and mitigation efforts by providing optimal solutions and mitigating challenges associated with multiple agent systems.

This work presents a process to obtain the shortest path between two points and thus minimizes the time and the distance of exposure of people or vehicles traveling through different risky scenarios. The recommended path can be provided to users through vehicle navigation systems, a smartwatch, or a smartphone.

Distributed intelligence in autonomous exploration robots: One of the challenges of autonomous exploration robots is to displace safely from the starting point to the arrival point in the shortest possible path (Amanatiadis *et al.,* 2013); (Chonnaparamutt & Birk, 2006); (Liu *et al.,* 2013); (5) Murphy, 2004; (11)Ponticelli Lima, 2010; (12) RamaKrishna, Sowmya Bala, S. N. Chakravarthy, Bhanu Prakash Sarma, & Sai Alla, 2012; (21) Vilela, Liu, & Nejat, 2013). Safety requirements imply the completion of tasks avoiding collisions, falling into holes, and mine detonations, among other risks. With this goal in mind, researchers have provided robots with specialized hardware and software. The evolution of software has been significant in that it has allowed the implementation of artificial intelligence (AI) (Kuhnt *et al.,* 2016). AI algorithms afford robots a certain level of decision-making capabilities, e.g., path planning algorithms (Estlin *et al.,* 2001); (3)Mac, Copot, Tran, & De Keyser, 2016). However, AI implementation demands the use of high processing and memory resources. Additional hardware requirements increase manufacturing costs of exploration robots. Said investment might be lost during dangerous tasks such as rescuing people in collapsed structures. Distributed intelligence (DI) has emerged as a less expensive option; for instance, the division of the main task into subtasks can be tackled by specific members of a team. The concept of capacity distribution not only helps in cost reduction, but also leads to better results in comparison to tasks performed by an individual. DI systems performance relies on the type of interactions of the individuals: collective, collaborative, coordinative or cooperative (9)(Parker, 2008). In the next section, some of this concepts are described that are relevant for the implementation of the techniques presented in this paper.

Directed graph: A graph (G) is composed of a set of elements called cross points (C), and a set of relationships called arcs (A). Formally, graphs can be represented as an ordered pair of sets (1)

$$G(C, A) \tag{1}$$

For practical purposes, $C_1, C_2, C_3, \ldots, C_n$, are defined as elements of C, as shown in (2).

$$C = \{C_1, C_2, C_3, \ \ldots, \ C_n\} \tag{2}$$

On the other hand, an arc can be considered as a set of three elements (C_i, C_j, l_{ij}), which establishes a relationship between the crossing points C_i and C_j, a sense of the relationship between the points $(C_i \rightarrow C_j)$, and a value or associated length (L_{i-j}). The graphic form of an arc is illustrated in Figure 1 (Guichard, n.d.); (J.s & M.R., 1996); (6) Murray-Lasso, 2003).

Fig. 1. Representation of an arc in a graph, adapted to introduce the notation used in this study.

Source: *Authors*

Simple directed graphs are highly recommended to represent path maps, which in turn favor the solution proposed herein and its implementation at the software level. Figure 2 shows a simple directed graph with four nodes $(C_1, C_2, C_3$ and $C_4)$, and three edges $(L_{1-2}, L_{2-3}, L_{3-4})$.

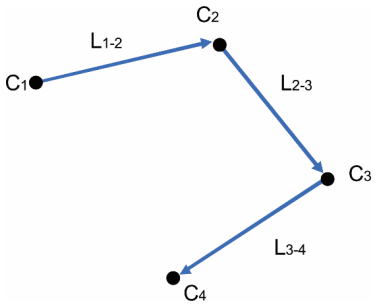

Fig. 2. Simple directed graph with four nodes (C_1, C_2, C_3, C_4) and three edges $(L_{1-2}, L_{2-3}, L_{3-4})$, adapted to explain the proposal in this study.

Source: *Authors*

Path planning: Path planning is a relevant topic in autonomous mobile robot research (Cho & Cho, 2014); (Espitia Cuchango & Sofrony Esmeral, 2012); (García *et al.*, 2007); (Latombe, 2012); (López García, 2011); (8) Ospina, Garzán, & Baldomiro, 2011). As the robots must perform tasks in the best conditions, some of the principal requirements for the path planners are (Bruce & Veloso, 2003); (Garrido *et al.*, 2007a); (Garrido *et al.*, 2007b); (Laumond *et al.*, 1994); (LaValle, 1998); (1)López, Gómez-Bravo, Cuesta, & Ollero, 2006; (19)Vargas, 2007): 1. Displacement from the starting to the arrival

point, 2. Safety displacement and 3. Obtaining the least-costly path. In this study, two explorer agents equipped with A* and GBFS (Greedy Best First Search Algorithm) path planners determine the path without collisions thanks to offset programming and sensors that detect obstacles. Later, the Shortest Estimated Path (SEP) will be obtained by a Monitoring and Management System (MMS), which will be introduced in Section II. The A* path planner was used because of its widespread use in Robotics literature (Fortune & Wilfong, 1991) ; (Koenig & Likhachev, 2002); (Koenig *et al.*, 2004a); (Kumar Das *et al.*, 2011); (2) Lozano-Pérez & Wesley, 1979; (7)Murray & Sastry, 1993; (15)Spangelo & Egeland, 1994; (16) Stentz, 1995) and, additionally, researchers have reported the following strengths: low consumption of processing resources, easy implementation, and simple programming changes (Duchon *et al.*, 2014); (Fernández, 2005); (Goyal & Nagla, 2014); (Koenig *et al.*, 2004a); (Konakalla, 2014); (4)Muntean, 2016; (13)Russell & Norvig, 2016; (14)Singh, Sharma, Sutton, Hatton, & Khan, 2018; (17)Sundfeld, Razzolini, Teodoro, Boukerche, & de Melo, 2018)The GBFS path planner was used due to a common base of construction with A* algorithm, which facilitates comparisons between them (Heusner *et al.*, 2018).

Gbfs algorithm (greedy best first search algorithm): The heuristic function of the GBFS Algorithm given by the equation (3).

$$f\left(n\right) = h\left(n\right) \tag{3}$$

Takes into account the following parameters:

n, nodes of the space to explore.

h(n), estimate of the distance from the current position of the explorer agent to the desired position. This estimate is obtained from concepts such as Euclidean or Manhattan distances, depending on the specific application. In this study Euclidean distances are used.

A* algorithm (a star algorithm): The heuristic function of algorithm A* takes into account the same parameters considered in the GBFS and includes a new one, *g(n).* The typical heuristic function for A* is shown in equation (4).

$$f\left(n\right) = h\left(n\right) + g(n) \tag{4}$$

The *g(n)* function estimates the cost of moving from the initial node to any other node (10)(Patel's, s/f). Finally, *f(n)* let's find the path with the lowest cost. Considering the aforementioned information, we present a cooperative strategy for the estimation of the shortest path from a starting point

to an arrival point by a team of autonomous robots. Slight differences among exploration agents are due to respective algorithms and settings of initial operating conditions. The results obtained herein present the shortest paths by cooperative strategy in comparison to those by each robot working individually (18)(Sunehag et al., 2018). The rest of this paper is structured as follows: The methods section presents a proposal of new variants of the GBFS and A* used in a Cooperative Strategy for Path Length Decrease (CSPLD), and their validation procedure. The results and discussion section describes a detailed analysis of one simulated environment and the measurement of the cooperative strategy contribution to obtain the SEP in 100 tests in ten different simulated environments. Finally, conclusions and future works sections are presented.

2 METHODOLOGY

Proposal of new variants of gbfs and a*: In order to prevent returns to an already visited node and to guarantee simple directed graphs, the authors added a new element *p(n)* to heuristic functions of the GBFS and A* algorithms. This is done by increasing the total cost function *f(n)* by adding a cost function *p(n)* to each node already visited (the chosen value of *p(n)* is 1). Equations (5) and (6) represent the enhanced heuristic functions for the GBFS and A*, respectively are.

$$f\left(n\right) = h\left(n\right) + p(n) \tag{5}$$

$$f\left(n\right) = h\left(n\right) + g\left(n\right) + p(n) \tag{6}$$

The heuristic functions are applied to each of the eight successor positions around the current position, but only the one containing the smallest value of *f(n)* will be chosen as the next best position. Algorithm 1 and algorithm 2, shows the pseudocodes for new path planners IH-GBFS and IH-A*, respectively.

Pseudocode for algorithm IH-GBFS.

textbfInivar()⇒ Initialize

$E = MXN$
$Vroute = [\,]$
$n = n_s \in E$
C()⇒ Cost function
$h(n', n_g) = d_E(n', n_g)$
$C(n, n') = f(n, n') = h(n) + p(n)$
Planif()⇒ Search process
$n' = Succ(n)$
$Vroute = C(n, n')\ \forall n' \in E$
$Bp_i = min(Vopen) \in E$
$n = n'_i \mid n_i \exists\, Bp_i \in E$
$return(n)$
Main()⇒ Main process
$Inivar()$
for(1)
$Planif()$
if(n==ng)
End of the search
End if
Update vertex
End for

Algorithm 1. Pseudocode for algorithm IH-GBFS.

Pseudocode for algorithm IH-A*.

Inivar()⇒ Initialize

$E = MXN$
$Nopen = [\,]$
$Nclose = 0$
$Vopen = [\,]$
$n = n_s \in E$
AddNopen()⇒ Update open nodes
$Nopen = [Nopen, n \in E]$
AddNclose()⇒ Update close nodes
$Nopen.r(n)$
$NClose = [Nclose, n]$
C()⇒ Cost function
$h(n', n_g) = d_E(n', n_g)$
$g(n, n') = d_E(n, n') + g^{\star}(n, n')$
$C(n, n') = f(n, n') = h(n) + g(n) + p(n)$
Planif()⇒ Search process
$n' = Succ(n) \in Nopen$
$Vopen = C(n, n')\ \forall n' \in E$
$Bp_i = min(Vopen) \in E$
AddNclose(n)
$n = n'_i \mid n_i \exists\, Bp_i \in E$
$return(n)$
Main()⇒ Main process
$Inivar()$
for(1)
$AddNopen$
$Planif()$
if(n==ng)
End of the search
End if
Update vertex
End for

Algorithm 2. Pseudocode for algorithm IH-A*.

A characteristic of the algorithms created by the authors is the retrieval of past events for each exploration agent, thus upgrading to incremental heuristic algorithms (IH-GBFS and IH-A*) (Koenig *et al.*, 2004b).

Cooperative strategy for path length decrease: Initially, in this section, two concepts will be defined: strategy and the cooperative process. Then, the Cooperative Strategy for Path Length Decrease (CSPLD) will be explained. A strategy is considered a detailed method or plan, chosen to achieve a goal or to solve a problem under conditions of uncertainty. A strategy describes how the goal will be achieved, whether its attainment depends exclusively on a fixed plan or the systems it is able to adapt to in its environment, according to the emergence of a particular pattern of activity. Since available resources are usually limited, the strategy resorts to the planning and organization of resources for an efficient and effective implementation. A strategy generally involves setting goals, determining actions to achieve those goals, and mobilizing resources to execute the actions (Freedman, 2015). A cooperative process is a type of DI, in which a team of agents works in unison to plan, solve problems, and learn (Hussein, 2018); (9)Parker, 2008). In this team, every member is aware of the other team members. The individual actions of each member of the cooperative team support the attainment of the main goal (Aljehani & Inoue, 2019); (Kim *et al.*, 2015). A team of two exploration agents and an MMS carries out the CSPLD, whose scheme is illustrated in Figure 3.

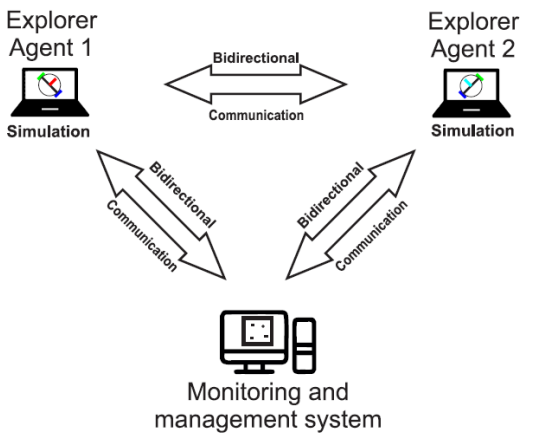

Fig. 3. Communication framework among two agents and the MMS applying the CSPLD to obtain the SEP.

Source: *Authors*

Each exploration agent uses its own path planner to create a path between start and goal points (Alje-

hani & Inoue, 2019). After the path planning process, each agent knows the position of its teammate. In order to obtain the SEP from data provided by the agents, the MMS computes, compares and combines paths of each agent (if possible) following the rules in Table 1.

Table 1. CSPLD cases and actions to determine SEP.

Source: *Authors*

No.	CASES	SEP ACTIONS
1	The two paths obtained are exactly the same.	**a. SEP selection:** The first path is chosen as the final path and designated as the SEP. Alternatively, the second path could be chosen based on different decision criteria such as fewer nodes, less control effort, or lower energy consumption during traversal.
2	The two paths obtained are different from each other, with equal traveled distances and no intersections.	
3	The two paths obtained are different from each other, with different traveled distances and no intersections.	**a. SEP selection:** The path with the shortest traveled distance is chosen as the SEP.
4	The two paths obtained are different from each other, with equal traveled distances and crossings in some sections.	**a. Crossing points location:** Crossing points are identified as (C1, C2, ..., Ci, Cj, ..., Cn). **b. Section definition:** A section is defined as the portion of paths between crossing points Ci and Cj.
5	The two paths obtained are different from each other, with different traveled distances and intersections in some sections.	**c. Comparison of paths:** The traveled distances of agents are compared in each section, and the shortest one is selected. **d. Combination of paths:** The concatenation of previously selected paths with the shortest distances results in the definitive path called SEP.

As seen in Table 1, each case matches a corresponding action, aiming to obtain the SEP. From the five

situations compared, only cases 4 and 5 imply path combinations; and only the fifth obtains a different SEP from previous paths found by exploration agents. Figure 4 corresponds to a representative environment of the fifth case. The dark and thick margin represents the offset associated with the border of the environment.

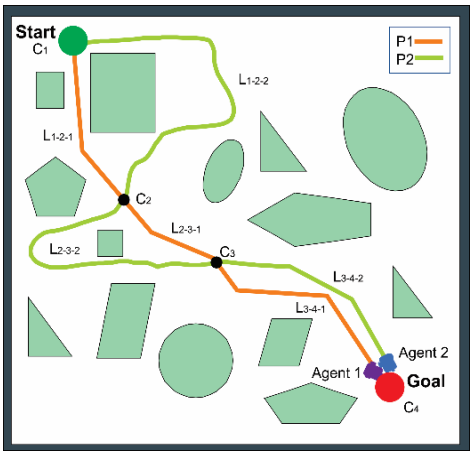

Fig. 4. Two agents and their paths (obtained with their respective path planners) are shown in a representative situation of the fifth case. This situation is used to explain the combination of paths in this study.

Source: *Authors*

For display effects to find the SEP, the following notation is defined (see Figure 4.):

$P1$: Orange path generated by agent 1.

$P2$: Green path generated by agent 2.

i: First sub index indicating the crossing point that precedes a path section, i=1to n-1.

j: Second sub index indicating the crossing point at the end of a path section, $j = 2$ to n.

k: Third sub index identifies agents, a path belongs to $k = 1$ or $k = 2$ (Agent 1 or 2 respectively).

C_i: Crossing point, from lowest (1) to highest (n), along the paths of agents $1, 2$.

L_{i-j-k}: Arc length traveled by agent k between crossing points C_i and C_j forming a path section.

S: Start point (C_1).

G: Goal point (C_4).

According to the previous notation in Figure 4, equation (7) and equation (8) are obtained.

$$P1 = L_{1-2-1} + L_{2-3-1} + L_{3-4-1} \tag{7}$$

$$P2 = L_{1-2-2} + L_{2-3-2} + L_{3-4-2} \tag{8}$$

Table 2 compares the sections of paths P1 and P2 between common crossing points of Figure. 4.

Table 2. Comparisons between the common sections of path P1 and path P2.

Source: *Authors*

Cross points	Section of P1	Comparison	Section of P2
$C_1 - C_2$	L_{1-2-1}	$<$	L_{1-2-2}
$C_2 - C_3$	L_{2-3-1}	$<$	L_{2-3-2}
$C_3 - C_4$	L_{3-4-1}	$>$	L_{3-4-2}

Equation (9) shows the result of the addition of the shortest path sections reported in Table 2. Moreover, Figure. 5 shows the SEP obtained by the CSPLD.

$$SEP = L_{1-2-1} + L_{2-3-1} + L_{3-4-2} \tag{9}$$

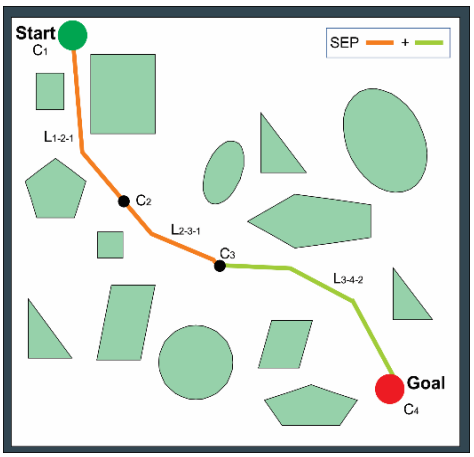

Fig. 5. Graphic example of the SEP obtained by the CSPLD implementation.

Source: *Authors*

Although Table 2 shows a particular solution (see Figure 4 and Figure 5) to find the SEP between P1 and P2, it is possible to generalize the same SEP procedure equation (9) for paths that have n crossing points in common (including the start and goal). In order to achieve such a generalization, j needs to be redefined in terms of i as shown in equation (10).

$$j = i + 1 \tag{10}$$

Finally, using the equation (10), the generalization of equation (9) is given by equation (11).

$$SEP = \sum_{i=0}^{n-2} min(l_{i-(i+1)-1}, l_{i-(i+1)-2}) \tag{11}$$

The generalization in equation (11) implies, at the software level, that all the cases previously described in Table 1 can be subject to the complete procedure of the SEP actions programmed for the fifth case in Table 1.

Validation procedure: This section validates the CSPLD effectiveness at the software level, whose mathematical formulation is given by equation (11). First, for the tests, IH-GBFS, IH-A* and MMS algorithms were coded in Matlab R2016a, running in Windows 10 on a Dell T7600 computer with an Intel Xeon processor of 2.40 GHz and installed RAM of 16 GB. Ten different environments with ten different positions of both start-to-goal points, were tested, resulting in 100 simulations of the cooperative strategy. Each test environment consists of a grid of 100 x 100 cells (as seen in Figure 6). Black cells represent obstacles, white cells correspond to empty spaces, and blue cells indicate the programmed offset to avoid collisions with the border of the obstacles (14). Green and red squares represent specific positioning of start and goal points respectively.

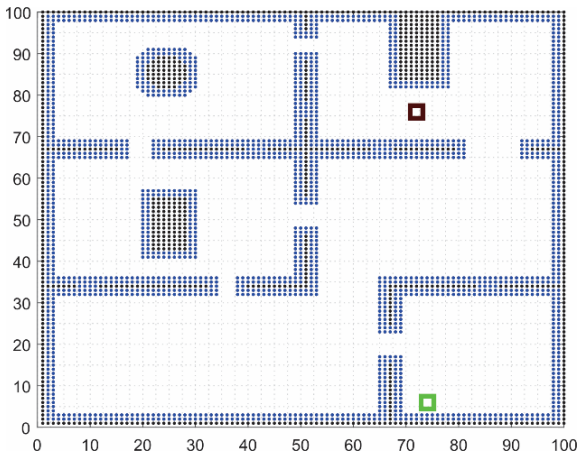

Fig. 6. Example of environment setting for the CSPLD simulations. In this study, the environment is labeled with the number 10, and is described as a two-dimensional square box of 100 cells per 100 cells, which has walls, free spaces, and three objects (one circle and two rectangles). This environment represents a house that has five rooms without doors. In two rooms, there is a rectangular object. In one room, there is a circular object.

Source: *Authors*

The implementation entails additional commutation of start and goal points, which leads to 200 partial SEP's before obtaining the definitive 100 SEP's. The results presented in the following subsection are summarized in tables with the subsequent nomenclature:

P1A: Distance from start to goal with path planner IH-A* (in cell units).

P1B: Distance from goal to start with path planner IH-A* (in cell units).

P2A: Distance from start to goal with path planner IH-GBFS (in cell units).

P2B: Distance from goal to start with path planner IH-GBFS (in cell units).

Data gathered from the 10 environments were subject to a four-table comparative analysis, whose most relevant estimations are as follows:

SEP P1: Distance of the partial SEP after applying cooperative strategy to P1A and P1B (in cell units).

SEP P2: Distance of the partial SEP after applying cooperative strategy to P2A and P2B (in cell units).

SEP: Distance of the definitive SEP after applying cooperative strategy to SEP P1 and SEP P2 (in cell units).

Finally, a percentage of the decreased length of original paths (P1A and P2A) in relation to the definitive SEP is obtained.

3 RESULTS AND DISCUSSION

Detailed analysis of one selected environment: Since the cooperative strategy and the type of collected data were the same for the ten tested environments, only detailed information corresponding to environment 10 will be presented for the sake of illustration (see Figure 6). This environment seeks to resemble a house that has five no-door rooms, in which three of them have a regular-sized object.

1. Data associated to the SEP P1 are found in Table 3. The first column in Table 3, identifies 10 different positions of start and goal points. Additionally, Table 3 illustrates percentages of the decreased path length given by equation (12) and equation (13), respectively. Figure 7 is an example (corresponding to test 5) comparing a partial SEP P1 with original P1A and P1B.

Table 3. The SEP P1 by cooperative strategy for environment 10.

Source: *Authors*

Test	Path length (cells)			% Decrease of path length	
	P1A	P1B	SEP P1	%P1A-SEP P1	%P1B-SEP P1
1	109.31	343.56	106.38	2.75	222.94
2	112.14	105.90	105.90	5.89	0.00
3	97.74	305.32	97.74	0.00	212.38
4	116.38	107.66	107.66	8.11	0.00
5	150.38	100.97	95.70	57.14	5.51
6	116.23	134.23	116.23	0.00	15.49
7	108.80	108.80	101.77	6.91	6.91
8	117.38	348.88	117.38	0.00	197.21
9	522.49	116.14	116.14	349.87	0.00
10	98.77	99.94	87.05	13.46	14.80

Where:

$$\%P1A - SEP\ P1 = \left| \frac{SEP\ P1 - P1A}{SEP\ P1} \right| * 100\% \tag{12}$$

$$\%P1B - SEP\ P1 = \left| \frac{SEP\ P1 - P1B}{SEP\ P1} \right| * 100\% \tag{13}$$

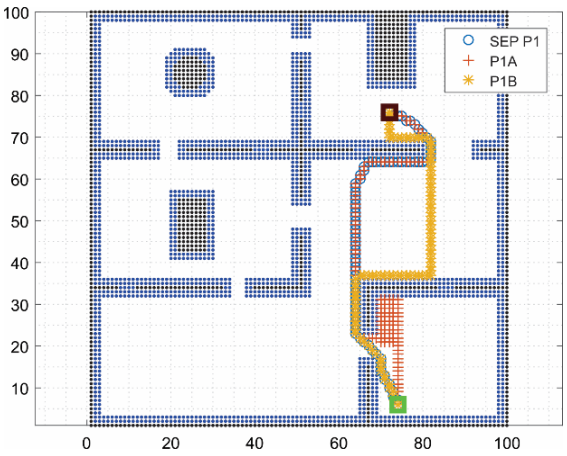

Fig. 7. The SEP P1 obtained by the CSPLD from P1A and P1B for environment 10, test 5

Source: *Authors*

2. Data associated with the SEP P2 are found in Table 4. The first column identifies 10 different positions of start and goal points. Additionally, Table 4 illustrates percentages of the decreased path length given by equation (14) and equation (15), respectively. Figure. 8 is an example (corresponding to test 5) comparing the partial SEP P2 with the original P2A and P2B.

Table 4. The SEP P2 by cooperative strategy for environment 10.

Source: *Authors*

Test	Path length			% Decrease of path length	
	P2A	P2B	SEP P2	%P2A-SEP P2	%P2B-SEP P2
1	219.84	353.98	112.08	96.14	215.82
2	114.87	114.87	106.08	8.28	8.28
3	97.74	435.83	97.74	0.00	345.91
4	123.36	151.60	109.40	12.76	38.58
5	764.12	651.76	97.18	686.27	570.65
6	132.61	164.51	132.61	0.00	24.06
7	108.80	108.80	101.77	6.91	6.91
8	479.62	379.68	379.68	26.32	0.00
9	345.18	106.18	100.33	244.06	5.84
10	138.67	171.74	87.05	59.29	97.28

Where:

$$\%P2A - SEP\ P2 = \left| \frac{SEP\ P2 - P2A}{SEP\ P2} \right| * 100\% \tag{14}$$

$$\%P2B - SEP\ P2 = \left| \frac{SEP\ P2 - P2B}{SEP\ P2} \right| * 100\% \tag{15}$$

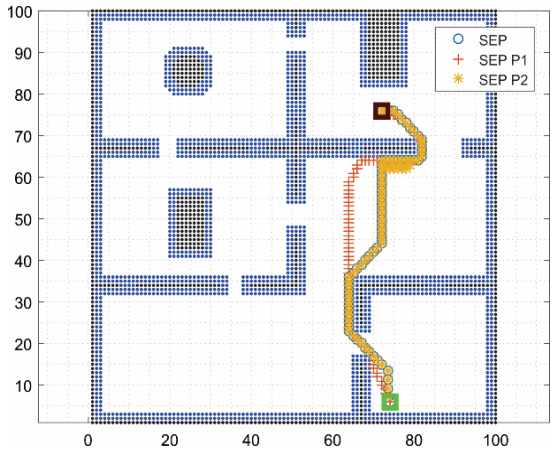

Fig. 8. The SEP P2 obtained by the CSPLD from P2A and P2B for environment 10, test 5.

Source: *Authors*

3. Data associated with the definitive SEP are found in Table 5. The first column identifies 10 different start and goal positioning points. Additionally, the table reports percentages of the decreased path length given by equation (16) and equation (17) respectively. Figure 9 is an example (corresponding to test 5) comparing the definitive SEP against the SEP P1 and the SEP P2.

Table 5. The definitive SEP by cooperative strategy for environment 10.

Source: *Authors*

Test	Path length			% Decrease of path length	
	SEP P1	SEP P2	SEP	%SEP P1-SEP	%SEP P2-SEP
1	106.38	112.08	106.38	0.00	5.36
2	105.90	106.08	102.77	3.05	3.22
3	97.74	97.74	97.74	0.00	0.00
4	107.66	109.40	104.14	3.37	5.05
5	95.70	97.18	80.11	19.45	21.31
6	116.23	132.61	116.23	0.00	14.10
7	101.77	101.77	101.77	0.00	0.00
8	117.38	379.68	105.08	11.71	261.31
9	116.14	100.33	100.33	15.76	0.00
10	87.05	87.05	87.05	0.00	0.00

Where:

$$\%SEP1 - SEP = \left| \frac{SEP - SEP\ P1}{SEP} \right| * 100\% \tag{16}$$

$$\%SEP2 - SEP = \left| \frac{SEP - SEP\ P2}{SEP} \right| * 100\% \tag{17}$$

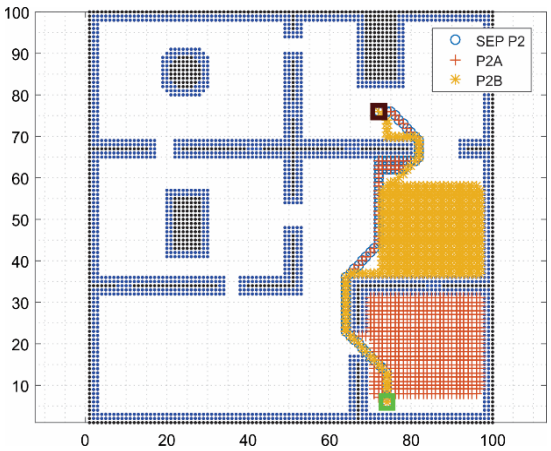

Fig. 9. The SEP obtained by the CSPLD from SEP P1 and SEP P2 for environment 10, test 5.

Source: *Authors*

4. The last two columns of Table 6 illustrate the percentage of the decreased length of original paths (P1A and P2A) with the definitive SEP obtained by equation (18) and equation (19), respectively.

Table 6. Comparison of the P1A and P2A paths vs the SEP using a cooperative strategy in environment 10.

Source: *Authors*

Test	Path length			% Decrease of path length	
	P1A	P2A	SEP	%P1-SEP	%P2-SEP
1	109.31	219.84	106.38	2.75	106.65
2	112.14	114.87	102.77	9.12	11.77
3	97.74	97.74	97.74	0.00	0.00
4	116.38	123.36	104.14	11.76	18.45
5	150.38	764.12	80.11	87.72	853.81
6	116.23	132.61	116.23	0.00	14.10
7	108.80	108.80	101.77	6.91	6.91
8	117.38	479.62	105.08	11.71	356.42
9	522.49	345.18	100.33	420.80	244.06
10	98.77	138.67	87.05	13.46	59.29

Where:

$$\%P1A - SEP = \left| \frac{SEP - P1A}{SEP} \right| * 100\% \tag{18}$$

$$\%P2A - SEP = \left| \frac{SEP - P2A}{SEP} \right| * 100\% \tag{19}$$

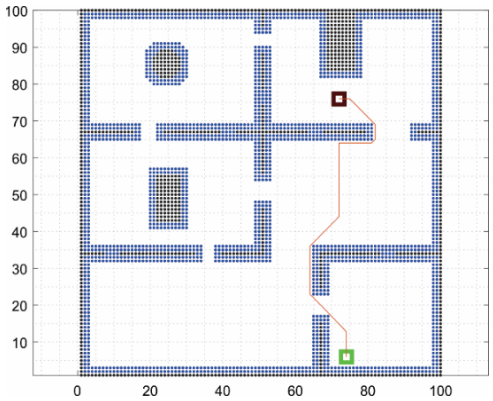

Fig. 10. The definitive SEP obtained in environment 10, test 5

Source: *Authors*

For the authors, cases with percentages greater than 0.00 are labeled as "successful", i.e., the CSPLD was capable of obtaining shorter paths in comparison to the ones initially given by path planners.

Figure 10 illustrates the definitive SEP for environment 10, test 5. As a last note, zeros reported in tables should not be regarded as results of implementation of the cooperative strategy without the MMS involvement. Indeed, null reductions of paths are only revealed after the MMS processing of information is provided by explorer agents.

Measurement of cooperative strategy contribution: Since the last decrease percentages (Table 6) are relevant to measure the contribution of this methodology, the tables of this section compile this indicator for the ten tested environments and their corresponding tests (100 tests for each of the two path planners). Said compilation will be presented from two different perspectives. The first compilation criterion selected is success "S", i.e., the number of tests in which the CSPLD achieved a decrease in the path length with respect to the original individual path planning (decrease percentages greater than 0.00). The second criterion to measure the contribution is called "%PKA-SEP", defined by the authors as the percentage of path decrease given by an agent K, between start and goal points in relation to the definitive SEP. Tables 7, 8 and 9 detail necessary information to assess the cooperative strategy according to the "success" criterion. Tables associated with this evaluation use the following nomenclature:

%S/IH-A*: Percentage of the CSPLD success with respect to the individual work of the IH-A* path planner.

Table 7. Percentages of CSPLD success with respect to the individual work of the path planners.

Source: *Authors*

Environment	**Tests**	**S**	
		%S/IH-A*	**%S/IH-GBFS**
1	1-10	90	80
2	11-20	90	90
3	21-30	90	70
4	31-40	90	80
5	41-50	90	100
6	51-60	50	40
7	61-70	80	70
8	71-80	80	70
9	81-90	80	70
10	91-100	80	90

After comparing information provided by Table 7, the CSPLD achieved a path reduction in most environments (at least in 70% of tests). However, tests on environment 6 diverged from this high rate of success, with a less successful reduction rate of 50 % of S/IH-A* and 40 % of S/IH-GBFS. The divergent results in environment 6 were due to some unchallenging positioning of start and goal points for this particular environment (depicted in Figure 11), proof of which is that this same environment presented three PA1–SEP percentages above 500% (see Figure 12).

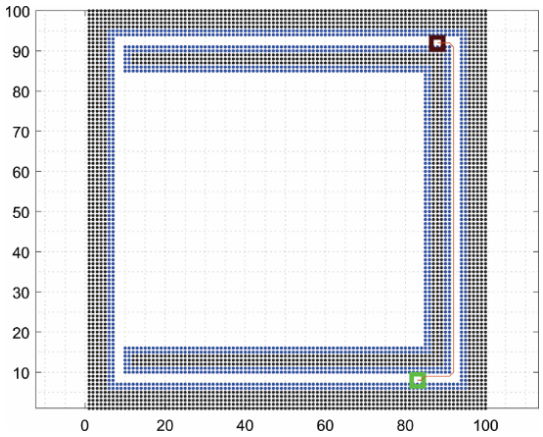

Fig. 11. Unchallenging positioning of start and goal points in setting of environment 6.

Source: *Author*

By averaging percentages of Table 7, the overall success of the whole experiment is given in Tables 8 and 9. The new tables have the following nomenclature:

%S/Path planner: Percentage of the total CSPLD success with respect to the individual work of each path planner.

%S: Percentage of the total CSPLD success in the experiment.

Table 8. Percentage of the total CSPLD success about the individual work of each path planner IH-GBFS and IH-A*.

Source: *Authors*

	Tests	**%S/Path planner**	
		IH-A*	**IH-GBFS**
Total 10 environments	100	82	76

Table 9. . Percentage of the CSPLD performance in relation to the individual work of the path planners IH-GBFS and IH-A*.

Source: *Authors*

	Tests	**%S**
Total	200	79

The CSPLD assessment based on the %PKA-SEP criterion requires the proportion of each de-

crease in percentage of the original path obtained by agent K in comparison to its corresponding definitive SEP. For such a purpose, Figure 12 illustrates reduction peaks, and zones of null reduction for all the ten tested environments and their respective ten tests (100 tests in total shown in the horizontal axis of Figure12). In Figure 12, the blue dotted line identifies reductions of the CSPLD in relation to IH-A*. The red line corresponds to reductions of the CSPLD in relation to IH-GBFS. Figure 12 illustrates a clear disparity between the most challenging least challenging environments for both planners (considering the particular start and goal positioning points). On tests 28 to 53, four significant peaks converge above 400% of the %PKA-SEP; conversely, in tests 55 to 60 and 67 to 70 two dips are noticed, in which the %PKA-SEP is zero or has a very low percentage of path decrease. With the purpose of giving the reader an idea of the general impact of the CSPLD, 20.5% of the performed tests obtained a SEP with reductions over 100% of the %PKA-SEP. Therefore, a definitive SEP by the CSPLD can be significantly shorter than the original path planned by IH-A* and IH-GBFS.

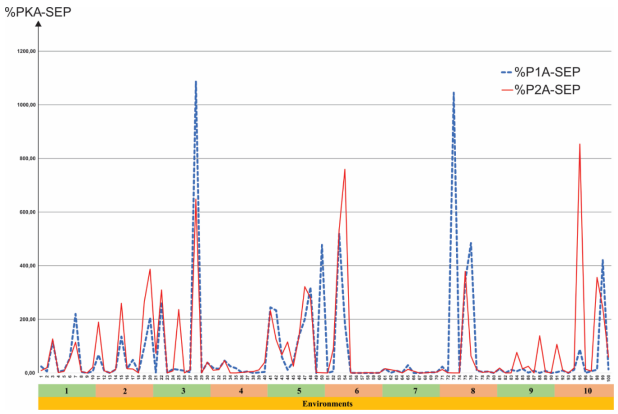

Fig. 12. CSPLD assessment based on %PKA-SEP.

Source: *Authors*

Even though it has not been tested in real environments, this research presents a promising strategy that holds potential for effectively safeguarding populations. While further validation in real-world scenarios is needed, the developed artificial intelligence system, with its distributed intelligence approach and utilization of heatmap and contour lines, shows promise in mitigating risks in COVID-19-prone environments. Its successful performance in simulations indicates the viability of employing this strategy for protecting populations from potential contagion threats.

Using the positions of hidden marks found in Figure 13(a) and using Equation 20 (considering $u = 1$);

are created simulations of R in Matlab; as seen in Figure 13 (b), and Figure 13 (c). Figure 13 (b) shows a top view of the Risk potential in a hot diagram (see colour scale) and Figure 13 (c) shows the Risk potential field, because of hidden marks found in Figure 13 (a).

$$R = \sum_{i=1}^{m} \frac{u}{d_j}; 0 < R < \infty \tag{20}$$

Where:

j: subscript describing the number of the mark found between a group from 1 to m

m: Total number of "hidden marks found"

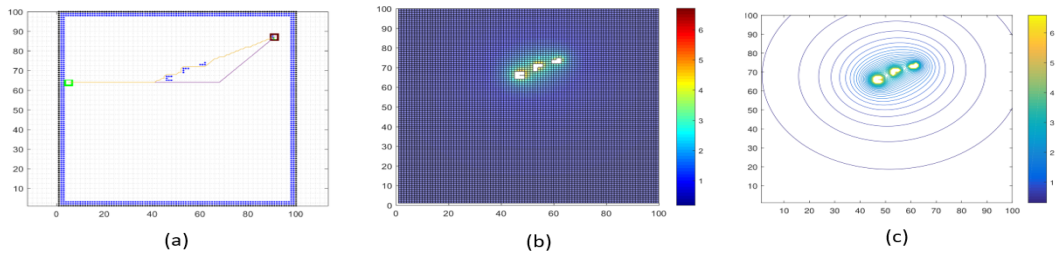

Fig. 13. (a) The initial point is colored green, and the target point is black. Additionally, three Covid-19 risk points are colored blue. (b) The heatmap in this figure illustrates the proximity risk around each point. (c) Lastly, the figure presents contour lines indicating areas with the same level of risk.

Source: *Authors*

4 Conclusions

In the analyzed environments, the CSPLD exhibited a significant rate of success overall, since it yielded path reductions for 79% of the 200 cases analyzed. The only environment diverging from this behavior demonstrates a "moderate" rate of success (45%) with a more challenging positioning of start and goal points. As far as path planners are concerned, the CSPLD achieved higher rates of success for IH-A* cases (82%) in comparison to those of IH-GBSF (76%). The overall rate of success in terms of path planners was 79%. Regarding the % PKA-SEP, it is evident that 14% of performed tests obtained a SEP with reductions of over 200%. Therefore, the definitive SEPs by the CSPLD can be significantly shorter than the original paths, planned by IH-A* and IH-GBFS. The aforementioned convergences of peaks point to the most challenging cases for both planners. The two algorithms

were quite inefficient in relation to the CSPLD. In these cases, the CSPLD delivered severe corrections to their original paths. In other words, the greatest contributions of the methodology were achieved in these cases. The dips defined above represent the least challenging specific cases for both planners. In these cases, the CSPLD offered slight corrections (under 10% of the %PKA-SEP). In other words, the less significant contributions of the methodology were demonstrated in these cases. Since the highest values of the %PKA-SEP were achieved in environments that challenged the algorithms individually, in these environments the potential of the CSPLD is revealed.

5 FUTURE WORKS

As a continuation of this study, explorer agents could work with different algorithms (e.g., Bug, D* or DFS) or, perhaps, modifications, such as interactions among path planners. Likewise, a collaborative interaction of the DI system can be selected, in which an agent could warn others about obstacles.

6 FUNDING

This work is funded in part by the Universidad Tecnológica de Pereira through the VIIE, Project Name: "Sistema de obtención de rutas más seguras bajo situación de pandemia caso covid-19," Project Code: 3-20-11, and in part by the Universidad Nacional de Colombia.

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https://revistas.udistrital.edu.co/index.php/Tecnura/issue/view/1201

DOI: https://doi.org/10.14483/22487638.19706

INVESTIGACIÓN

Factors Influencing University Technological Transfer in Colombia

Determinantes de la Transferencia Tecnológica Universitaria en Colombia

Jaime Enrique Sarmiento Suárez [1], Juan Camilo Galvis Ciro [2],

Fecha de Recepción: 19 de Julio de 2022 **Fecha de Aceptación**: 22 de Junio de 2023

Cómo citar: Sarmiento-Suárez, J.E. y Galvis-Ciro, J.C. (2023). Factors Influencing University Technological Transfer in Colombia. *Tecnura*, **27**(78), 73-102. https://doi.org/10.14483/22487638.19706

ABSTRACT

The formal university technology transfer (TTU) in Colombia can contribute significantly to the country's economic development. Based on the Theory of Resources and Capacities, this paper investigates the determinants of transfer in Colombian public and private universities. For this, we used structural equations methodology from data collected through a survey of 20 Colombian universities. The results of the estimates empirically confirm the significance of the financial, commercial, cultural, and human dimensions in the technology transfer process. Among the main factors that positively influence the TTU are: 1. the importance of external financial resources, 2. having a technological portfolio, 3. the time that transfer activities have been carried out, and 4. the people in charge's experience.**:** The study shows us that it is necessary to strengthen policies within universities and improve their articulation with firms to achieve more successful technology transfer processes.

Keywords: Technology transfer, structural equations, resources.

[1]Doctor en Gestión de la Tecnología y la Innovación, Ingeniero de Sistemas e Ingeniero Industrial. Profesor Facultad de Administración de Negocios Internacionales, Universidad Pontificia Bolivariana. Bucaramanga, Colombia.
Email: jaimesar1@hotmail.com
[2]Doctor en Economía, Economista. Profesor Facultad de Economía, Universidad Pontificia Bolivariana. Medellín, Colombia.
Email: jcgalvisciro@gmail.com

Resumen

La transferencia tecnológica universitaria (TTU) formal en Colombia puede contribuir de manera significativa al desarrollo económico del país. Basado en la Teoría de los Recursos y las Capacidades, este trabajo investiga los determinantes de la transferencia en las universidades públicas y privadas colombianas. Para esto, es utilizada la metodología de ecuaciones estructurales a partir de datos recopilados mediante una encuesta a 20 universidades colombianas. Los resultados de las estimaciones confirman empíricamente la significancia de las dimensiones financiera, comercial, cultural y humana en el proceso de transferencia tecnológica. Entre los principales factores que influyen positivamente en la TTU, se encontró: 1. la importancia que tienen los recursos financieros externos, 2. el contar con un portafolio tecnológico, 3. el tiempo que se lleva realizando actividades de transferencia y 4. la experiencia de las personas encargadas. El estudio nos muestra que es necesario fortalecer las políticas al interior de las universidades y mejorar su articulación con las empresas para lograr procesos de transferencia tecnológica más exitosos.

Palabras clave: Transferencia tecnológica, ecuaciones estructurales, recursos.

1. Introduction

The university-industry relationship is important for the development of science and technology in each country (Méndez *et al.*, 2016) (Andrade *et al.*, 2016) (Liew *et al.*, 2012). In general, it can be said that this relationship is the nucleus for research, development, and technology transfer processes for economic growth. In the last decade, the creation of academic spin-offs has strengthened or revitalized the economy in regions that had a decline in their traditional industries (Gorman & McCarthy, 2006). Likewise, they have become a driving force for high-tech industrial clusters. (Rogers *et al.*, 2001). Consequently, the transfer of technology between the university and the industry is a relevant factor in creating competitive advantages for the host organizations and helps to generate wealth in the environment in which it is developed.

To strengthen the university-industry relationship, the United States, facilitated the passage of legislative acts such as the Bayh-Dole Act, the Stevenson-Wydler Technology Innovation Act, the National Cooperative Research Act, the Federal Technology Transfer Act, and the National Law of Transfer and Advancement of Technology. These laws created an environment conducive to strengthening the relationship between the university and the industry while facilitating technology transfer processes. In Latin American countries, laws have also been passed to enhance research, development, and innovation. In the Colombian case, Law 29 of 1990 to promote scientific research, Decree 585 of 1991 that created the National Council of Science and Technology, and Law 128 of 2009 that transformed

Colciencias stand out.

In Latin America, technology transfer processes in the business sector have not yet been consolidated despite enacting of different laws, although governments and universities have made great efforts to strengthen them (Vazquez, 2017). Since 2015, Latin American universities have sought to differentiate themselves in a career in which the importance of their work and the possibilities for development depend on the ability to evolve and find new ways and structures to put knowledge at the service of society (Arechavala & Sanchez, 2017) , Latin American universities have defined strategies to institutionalize the transfer processes and carry out the commercialization of goods or services to the communities closest to their surroundings.

In the case of Colombia, the problems have been diverse. Despite efforts to try to strengthen collaboration between universities and companies, these relationships have not been effective. (Méndez *et al.*, 2016) confirms a gap between entrepreneurs and researchers and identify factors affecting both. These factors include the lack of empathy between the parties, lack of conditions to obtain face-to-face feedback with the business community, lack of resources, poor communication between the employer, the researcher, and the government, among others (Méndez *et al.*, 2016)

It is also important to note that the Congress of the Republic of Colombia, to encourage the dissemination and transfer of technology from universities, approved Law No. 1838 of July 6, 2017. This law seeks to promote science, technology, and innovation in the country by creating technology-based companies. The objective is to promote innovative entrepreneurship in universities and take advantage of research results to benefit society (Congreso de Colombia, 2017). The norm enables public and private universities to create spin-offs, with researchers who develop essential technologies for the company, combined with tax incentives to exploit intellectual creations (Spin-Off Colombia, 2018).

Law 1838 is essential to promote technology transfer. The relationship between universities and companies is fundamental, but it is necessary to have a base of resources and capacities that create of a conducive and suitable environment for transferring university technology in Colombia. Not only is it enough for universities to declare themselves entrepreneurs, but they must also adapt their policies and organizational structures, giving space, for example, to the Research Results Transfer Office (OTRIs for its acronym in Spanish) (Algieri *et al.*, 2013). It is also necessary to help universities fulfill the role of administrators and protectors of the intellectual property generated within them, the gene-

ration of incentive policies for university personnel, among other relevant aspects in the dynamics of transfer and management of technological innovation (Berbegal *et al.*, 2015). In conclusion, the challenge for Colombian universities is related to detecting, analyzing, and managing the factors that influence technology transfer and, in this way, guiding administrators to improve these processes.

This paper focuses on inter-organizational university-company technology transfer based on the traditional theoretical model associated with business opportunities. The objective is to identify the determinants of the technology transfer process of the universities and analyze how the transfer is taking place in Colombian universities (public and private). For this, this research seeks to establish what are the existing relationships between the different resources (commercial, institutional, financial, human) of the universities that allow understanding the transfer process, based on the number of license agreements, technological cooperation, and creation of technology-based companies that have registered. Given the complexity of the situation to be studied, are used multivariate techniques, especially the partial least squares method for structural equations. The results show that financial, commercial, human, and cultural resources are significant for Colombian universities. Mainly, the indicators related to human capital determine factors, such as researchers, the technology portfolio that the institution has, the time it has been carrying out technology transfer activities, and the external financial resources that support research and development.

The structure of the document is as follows: In section 2, the literature review. Section 3 the methodology. Section 4 presents the estimates and results. Finally, section 5 presents the conclusions of the work.

2. LITERATURE REVIEW

There is scientific literature that shows how universities can make relevant contributions to increase the economic performance of companies and meet social needs, both in developed and developing countries. (Klofsten *et al.*, 2019); (Audretsch & Link, 2017); (Cassiman *et al.*, 2010); (Maculan & Carvalho, 2009); (Perkmann & Walsh, 2009).

Empirical studies demonstrated the contribution of technology transfer processes carried out, mainly, by universities in North America and Europe, which positively impacted their environments. The results of these processes were measured in terms of contributions to the creation of a specialized

workforce (Bound *et al.*, 2019); (Ishengoma & Vaaland, 2016); (Bessette, 2003), income obtained from patents, research and development collaborations (Siegel, Waldman, & Link, 2003), spillover effects (Audretsch *et al.*, 2005) and total college income, among other results (Goldstein, 1990).

On the other hand, the main expenses to develop the transfer are associated with the direct costs to build the innovations (Bessette, 2003); (Goldstein, 1990), the fees to register patents, and the personnel costs (Roessner *et al.*, 2013); (Siegel *et al.*, 2003); (Martin, 1998). Other studies also relate the economic impact of transfer processes with the change in the countries' gross domestic product (GDP) (Roessner *et al.*, 2013); (Martin, 1998).

In the case of developing countries, there is little evidence and information regarding the impacts and measurement of technology transfer from the perspective of universities. Most of the studies that exist are descriptive in nature and serve as a means of obtaining essential information to diagnose the current state of the transfer (Dutrenit & Arza, 2015); (Medina *et al.*, 2014); (Caldera & Debande, 2010); (Cimoli *et al.*, 2005).

In this regard, (Dutrenit & Arza, 2015) analyzed the interaction between universities and companies and took the countries of Argentina, Brazil, Costa Rica, and Mexico as a case study. They used two types of surveys; one aimed at R&D companies and managers, and the other at academic researchers. The study showed that the commercial channel is relatively unimportant in transfer processes, while informal interactions are relatively more used, such as conferences or different types of informal information exchange. Additionally, researchers from the four countries assigned greater importance to any channel other than companies. They also found that researchers from Brazil and Costa Rica tend to prefer traditional channels (publications and conferences). In Argentina, they like the service channel (consultancies), and in Mexico, the bidirectional channel (joint R&D). On the business side, channels are concentrated in the traditional media, like, hiring recent graduates.

In the case of Colombia, few studies have been carried out on the transfer of technology from universities to the industry to explain why some universities are more successful in these processes. There is, for example, the study by (Vasquez, 2008) , who considers that a more effective relationship between industry and the university in Colombia is essential. To this end, cooperation agreements are proposed that allow basic and applied research to move to a faster commercialization process to enable universities to obtain economic benefits in the short term.

In another study, (Arias & Aristizábal, 2011) consider that the community should be a natural recipient of the knowledge created by universities in addition to Industry and the State. In their results, the most common mechanisms used by the analyzed universities were public disclosure and public contracting to carry out social projects.

There is another crucial empirical work, and it is the one carried out by (Lizarazo *et al.*, 2015). This study found that public universities are interested in commercializing their technologies, but more than half have not achieved this objective, which could be the product of little experience in transfer processes.

(Méndez *et al.*, 2016), analyze the gap between the entrepreneur and the researcher in Colombia. This study shows some of the cognitive, affective, and situational factors that influence the approach of the company-researcher relationship in R&D or Transfer projects. According to (Méndez *et al.*, 2016), there is a gap of interests between the entrepreneur and the researcher because the actual needs of this complex relationship are not taken into account to achieve efficient and effective collaboration.

On the other hand, Donneys and Blanco (2016) affirm that the research of public and private universities in Colombia and the transfer of its results present difficulties due to the miniature tradition in this field and little investment by the state, which has caused some universities to undertake research corporately. In turn, according to (Donneys & Blanco, 2016), Colombian companies that invest in research do so mainly for technological modernization and use a tiny percentage for research and development. They also find that in Colombia, the orientation of researchers towards technology transfer is shallow, the promotion of business culture is weak, the university identification of opportunities to create companies presents problems and the technology transfer offices have a low level of independence in the aspects of financing, objectives, actions, and location. In short, according to the existing literature, the factors identified as critical in the technology transfer processes (human, cultural, institutional, financial, and commercial resources) present a dynamic that does not favor the transfer of technology from universities to the Colombian economy.

3. METHODOLOGY

Design.

Public resources obtain an essential return in the hands of the universities due to their potential so-

cial and economic effects. According to (Foltz *et al.*, 2000), public financing of university research processes is vital to strengthen technology transfer. Furthermore, authors such as (O'Shea *et al.*, 2005) consider that public resources make it easier for researchers to develop a specific variety of technology for subsequent commercialization.

Although public funding is essential, it is also important to note that studies indicate that industry funding is a necessary factor in technology transfer (see (Link & Siegel, 2005)). This type of alliance promotes, among other aspects, technology licensing activities and finances expenses for the protection of intellectual property (Chapple *et al.*, 2005). Given these aspects, the first hypothesis of the work is:

H1: Public and private financial resources positively affect university technology transfer.

On the other hand, as (O'Shea *et al.*, 2005), pointed out, having quality scientists promotes university transfer processes since it increases the probability of contributing basic and applied discoveries. Other studies, such as that of (Lach & Schankerman, 2004), consider that the size of the teaching body or the number of full-time researchers are critical inputs for technology transfer since the most prominent universities have greater capacities to carry out research work.

Transfer offices also play an essential role in the commercialization of technology; for this reason, authors such as (Chang *et al.*, 2006), consider that the size of these offices is a determining factor in the performance of the technology transfer process. Given this, the second hypothesis proposed in this work is the following:

H2: Human resources positively affect university technology transfer.

The transfer is a process that requires marketing skills. Authors such as (Mian, 1996) consider that intermediaries in transfer processes, such as having business incubators and marketing offices, play an essential role in the commercialization of technologies. For their part, (Lichtenthaler & Ernst, 2010) consider that the patent portfolios offered to the market are key in technology transfer processes since they are a sample of universities' past experiences in these processes. Given this, the third hypothesis

of the work is:

H3: Commercial resources have a positive impact on university technology transfer.

According to the academic literature, there are cultural factors that promote transfer processes. Authors such as (Siegel *et al.*, 2007) detected that the culture of the organization and the incentives help capture the collaboration of researchers towards the technology commercialization processes. On the other hand, (O'Shea *et al.*, 2005) consider that participation in royalties or profits positively affects technology transfer.
The work of (Siegel *et al.*, 2004) considers that having experienced employees in the transfer offices of the universities can more efficiently promote the commercialization of technology to the industry. Other studies show that the location of the university and the surrounding cultural context are factors that significantly affect the performance of university technology transfer. From this, the fourth hypothesis of the work is:

H4: Cultural resources positively affect university technology transfer.

In sum, to evaluate technology transfer in Colombian universities, this work proposes a theoretical model based on financial, cultural, human, and commercial factors as determinants of transfer. According to the hypotheses, the general model is the following:

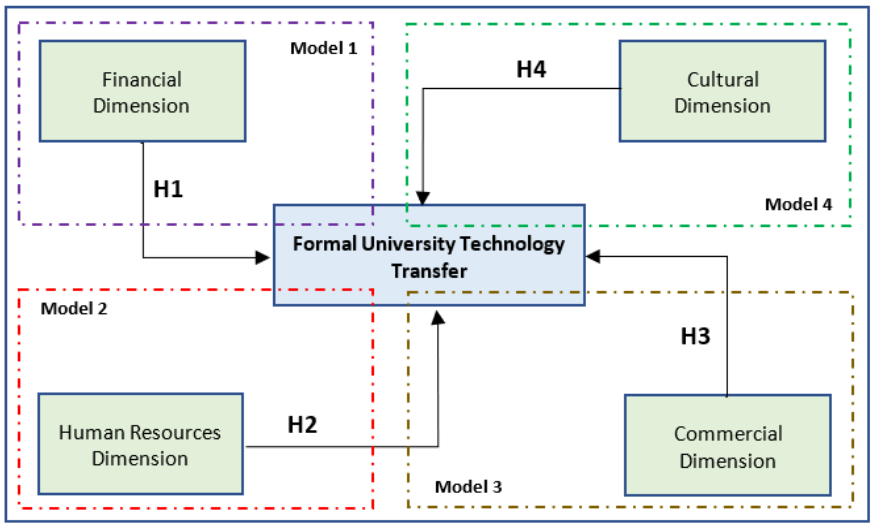

Figure 1. Research hypothesis

Source: *Authors*

Based on measurement scales from other empirical studies, the model variables were measured. The following table shows the number of indicators or items used to measure the different variables:

Table 1. Dimensions, indicators y authors

Source: *Authors*

Input variables		Authors
Dimension	**Indicators**	
Financial	4	(O'Shea, Allen, Morse, O'Gorman, & Roche, 2007; Chang, Chen, Hua, & Yang, 2006; Chapple, Lockett, Siegel, & Wright, 2005; Lizarazo M. , Jaime, Camacho, & Martinez, 2015; Bessette, 2003)
Human	4	(O'Shea, Allen, Morse, O'Gorman, & Roche, 2007; Lach & Schankerman, 2004; Friedman & Silberman, 2003; Chang, Chen, Hua, & Yang, 2006)
Commercial	4	(Mathews & Hu, 2007; Chapple, Lockett, Siegel, & Wright, 2005; Lichtenthaler & Ernst, 2010; Lizarazo M. , Jaime, Camacho, & Martinez, 2015)
Cultural	6	(Chapple, Lockett, Siegel, & Wright, 2005; Friedman & Silberman, 2003; Chang, Chen, Hua, & Yang, 2006; Carlsson & Fridh, 2002; Mathews & Hu, 2007; Siegel D. , Waldman, Atwater, & Link, 2004)
Output variable		
Formal University Technology Transfer	3	(Daim & Ozdemir, 2012; Siegel, Waldman, & Link, 2003; Simha, 2005)

Next, each item used by dimension is presented, along with the measurement scale used:

i) Indicators associated with the Financial Dimension: in this case, four items associated with owner financing, protection expenses, government financing, industry financing, and operating income were used.

Table 2. Measurement of the Financial Dimension

Source: *Authors*

Identifier	***Determinant***	***Measurement***
P4.2_Por_Rec_Pro_ID	Own financing	Indicates the percentage of own resources allocated by the university to R&D activities about operating income.
P5.2_Por_Rec_Pub_ID	Government financing	Shows the percentage of public resources received from State entities allocated by the university to R&D activities concerning operating income.
P6.2_Por_Rec_Priv_ID	Industry financing	Mesures the percentage of private resources received from companies destined by the university to R&D activities about operating income.

ii) Indicators associated with the Human Dimension: this dimension was measured by four items associated with the number of researchers and their quality, the size of the transfer offices, and the number of research groups.

Table 3. Measurement of the Human Dimension.

Source: *Authors, All variables are quantitative*

Identifier	***Determinant***	***Measurement***
P2.1_Num_Inv_S	Number of Senior researchers	It measures the number of researches classified as Senior accoding to Minciencias.
P2.2_Num_Inv_A	Number of associated researchers	It measures the number of researches classified as Associate accoding to Minciencias.
P16_Num_prof	Size of technology transfer offices	It presents the number of professionals who support the commercialization and technology transfer process at the university.
P2.5_Tot_Gr_A1_A	Number of research groups	It indicates the total number of research groups in categories A1 y A.

iii) Indicators associated with the Commercial Dimension: this dimension was measured by four items associated with the patent portfolio, international patents, invention disclosures, and interme-

diaries.

Table 4. Measurement of the Commercial Dimension

Source: *Authors, All variables are quantitative*

Identifier	***Determinant***	***Measurement***
P33_Pat_inv_con	National patent portfolio	It measures the total number of invention patents and utility models thet have been granted to universities by the SIC (Superintendence of Industry and Commerce) to date.
P35_Pat_inv_PCT	International patent portfolio	Indicates the number of invention and utility model patents that have been granted to universities by the PCT (Patent Cooperation Treaty) to date.
P31_Div_sel	Disclosures of the invention	Indicates the bumber of disclosures of technologies selected to protect per year between 2009 and 2018.
P12.2_Cant_Inter	Intermediaries	Measures the number of intermediaries that the university has to promote University Technology Transfer (Incubators and Techology Transfer Offices)

iv) Indicators associated with the Cultural Dimension: this dimension was measured by six variables related to the age of the transfer offices, the staff's experience, the tradition of research, the incentive policy, and the participation in royalties.

Table 5. Measurement of the Cultural Dimension

Source: *Authors, All variables are quantitative*

Identifier	*Determinant*	*Measurement*
P14.2_Ano_Ant_OTT	Transfer office age	Measures the number of years that the unit or position in charge of technology transfer and commercialization activities has been created.
P15_An_Exp_Resp	Transfer manager experience	Indicates the number of years of experience in charge or technology transfer and commercialization activities.
P0.2_Rank	Tradition in research	It contains the university's position concerning the U-Sapiens Classification Ranking of 2019.
P24.2_Can_Inc_TTU	Incentive policy	Indicates the total number of incentives used by the university to promote technology transfer.
P26_Porc_Reg	Royality share	Indicates the percentage of royalities assigned to inventors due to the commercialization of their inventions.
P41_IDIC	Innovation index associated with the university's location	It is a departamental innovation index that seeks to consider the enviroment where each university is located.

The primary variable of this study, technology transfer, was used three items to measure the transfer classified as formal. These were the sum of all the transfer indicators (the total number of paid and free license agreements, technological cooperation contracts, and the number of Spin-Off companies), the number of licenses, and the number of licenses generated revenue.

Participants.

This study used Colombian public and private universities with high research indicators as a data sample since, according to the literature, there is a strong relationship between research and technology transfer (Pich, 2020); (Audretsch & Link, 2017).

The specialized ranking in Colombia that classifies universities according to research criteria is the U-Sapiens ranking prepared by the consulting firm Sapiens Research, an entity recognized by the international observatory IREG. Based on the above, it was selected a sample of universities that were part of the 2019 classification. This classification determines only 74 institutions from more than 360 active higher education institutions in Colombia, which became the reference framework for this study. Within the 74 institutions that appear in the ranking, the headquarters of some of these

Table 6. Indicators of University Technology Transfer

Source: *Authors, All variables are quantitative*

Identifier	*Determinant*	*Measurement*
P10.1_Suma	Sum of all formal transfer indicators	It presents the total number of paid and free license agreements, technological cooperation contracts, and the number of Spin-Off companies carried out during five years (2014 – 2018) by the universities.
P38_Lic	Number of licenses	Indicates the number of licenses carried out by universities broken down by national or international without taking software licensing into account.
P39_Num_Lic_Ing	Number of revenue generating licenses	It mesuares the number of licenses that have generated income for universities.

institutions are included. By eliminating the venues, only 61 institutions remain in the order.

About the size of the sample, in this work, the criterion exposed by (Falk & Miller, 1992) and (Bentler & Chou, 1987), was used, which suggests collecting information from 5 cases for each latent variable that, in the more complex model presented in this work, contemplates three latent variables. Therefore, it is necessary to have a minimum number of 15 cases or units. Based on this criterion, information was initially collected from 15 public and private universities in Colombia in this study. However, additional information was collected from another five universities to obtain better results. In total, the sample size was 20 universities.

Instruments.

For the collection of information, this work used a survey made up of 40 questions that sought to measure the different aspects related to the financial, cultural, human resources, and commercial dimensions linked to the formal technology transfer process of the universities.

Different literature was reviewed to prepare the survey. The works carried out by authors such as (Lizarazo *et al.*, 2015), (Hsu *et al.*, 2015), (Yeverino, 2015), among others, who analyzed the technology transfer process in universities, were essential for the preparation of the survey. Before applying the study, it was validated with four experts in technology transfer; two researchers and two heads of technology transfer offices. They made observations and suggestions taken into account to prepare the final survey.

The information collection period was between June 2019 and May 2020. The people involved in providing the information were headed by the research vice-chancellors, academic vice-chancellors, and those responsible for the technology transfer processes of the University. The survey was sent via email and is available upon request to the authors.

4. RESULTS

This study uses the method of structural equations with least squares to estimate four models that correspond to the financial, commercial, cultural, and human dimensions. It is essential to note that the number of marketing mechanisms used by universities to bring technologies to the business sector (P10.1_Suma), the number of licenses carried out (P38_Tot_Lic), and the number of permits that have generated revenue (P39_Num_Lic_Ing) are the dependent variables used for each model. The results are presented below.

Model proposed for the Financial Dimension

The model presents two first-order constructs, called "Internal Resources" and "External Resources" Next, the proposed model is presented with the path coefficients and the external loads corresponding to the relationship between the constructs and their indicators.

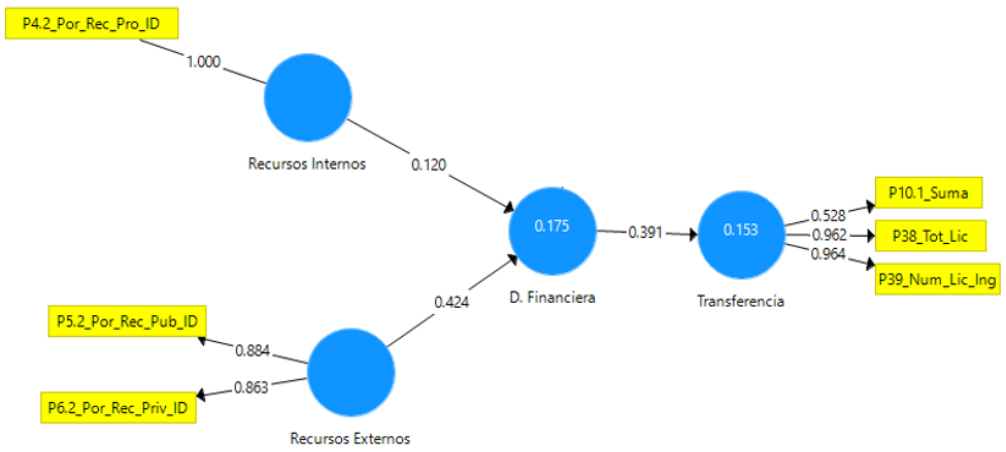

Figure 2. PLS Results proposed model Financial Dimension

Source: *Authors*

Next, the model goodness-of-fit statistics for the reflective and structural models are presented. Table

7, shows that the model meets: the criteria of convergent validity, internal consistency reliability, discriminant validity, and collinearity.

Table 7. Reflective measurement model results

Source: *Authors*

Variable latente	Indicadores	VALIDEZ CONVERGENTE		FIABILIDAD DE CONSISTENCIA INTERNA	
		Cargas (λ)	AVE	Alfa de Cronbach	Fiabilidad Compuesta
		≥ 0,40	≥ 0,50	≥ 0,60	≥ 0,60
	P4.1_Rec_Pro_ID	1,000	1,000	1,000	1,000
Recursos Externos	P5.1_Rec_Pub_ID	0,884	0,763	0,691	0,866
	P6.1_Rec_Priv_ID	0,863			
Transf_Tecn_Formal	P10.1_Suma	0,528	0,711	0,766	0,874
	P38_Tot_Lic	0,962			
	P39_Num_Lic_Ing	0,964			

Table 8. Discriminant validity

Source: *Authors*

VALIDEZ DISCRIMINANTE				
Criterio de Fornell – Larcker				
Variable latente	Dimensión Financiera	Recursos Externos	Recursos Internos	Transferencia
D. Financiera	1,000			
Recursos Externos	0,402	0,874		
Recursos Internos	0,039	-0,190	1,000	
Transferencia	0,391	0,832	-0,057	0,843

The proposed model showed that the two constructs (Internal Resources and External Resources) jointly explain 17.5 % of the variance of "Financial Dimension,.ªnd the latter explains 15.3 % of the endogenous construct Formal Technology Transfer variance.

The results show that only the indicators corresponding to External Resources present significant coefficients and effects. In addition, the coefficient associated with the Financial Dimension is essential in explaining the transfer (see table 9).

Source: Author. Note: * $p < 0{,}05$; ** $p < 0{,}10$; NS (Not significant).

The results show that only the indicators corresponding to External Resources present significant coefficients and effects (see, Table 11). Specifically, .Externalal Resources"have a more significant effect $(0{,}424)$ on the Formal Technological Transfer of Universities (Transf_Tecn_Formal) and the coefficient

Table 9. Total effects significance test results

Source: *Authors*

	Efecto total	Valor t	Valor p	Significancia
D. Financiera -> Transferencia	0,391	3,760	0,000	*
Recursos Externos -> D. Financiera	0,424	2,916	0,004	*
Recursos Externos -> Transferencia	0,266	2,768	0,006	*
Recursos Internos -> D. Financiera	0,120	0,682	0,495	NS
Recursos Internos -> Transferencia	0,047	0,508	0,611	NS

associated with the Financial Dimension is essential in explaining the transfer.

Model proposed for the Commercial Dimension

Two constructs were proposed for the model that supports the Commercial Dimension: "Technological Portfolio.ªnd Ïntermediaries."Next, the proposed model is presented with the path coefficients and the external loads corresponding to the relationship between the constructs and their indicators.

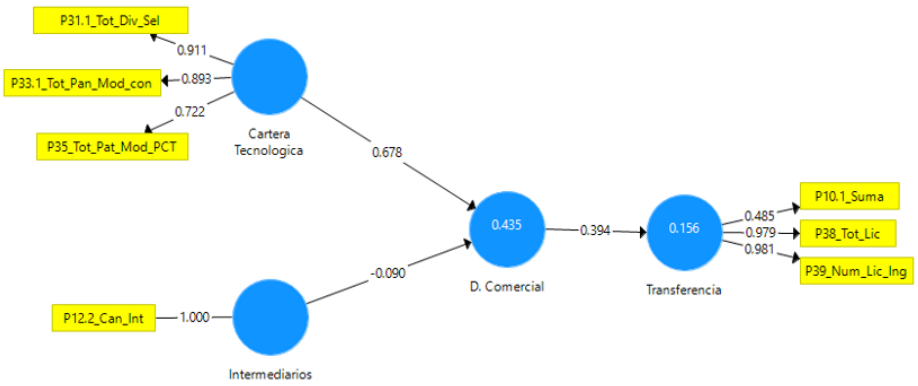

Figure 3. PLS Results proposed model Commercial Dimension

Source: *Authors*

The different tests are presented to determine the validity of the measurement model. According to the results, the model is reliable.

Table 10. Convergent validity and internal reliability results

Source: *Authors*

Variable latente	Indicadores	VALIDEZ CONVERGENTE		FIABILIDAD DE CONSISTENCIA INTERNA	
		Cargas (λ)	AVE	Alfa de Cronbach	Fiabilidad Compuesta
		≥ 0,40	≥ 0,50	≥ 0,60	≥ 0,60
Cartera Tecnológica	P31.1_Tot_Div_Sel	0,911	0,716	0,799	0,882
	P33.1_Tot_Pan_Mod_con	0,893			
	P35_Tot_Pat_Mod_PCT	0,722			
Intermediarios	P12.2_Can_Int	1,000	1,000	1,000	1,000
Transferencia	P10.1_Suma	0,485	0,719	0,777	0,876
	P38_Tot_Lic	0,979			
	P39_Num_Lic_Ing	0,981			

Table 11. Discriminant validity

Source: *Authors*

VALIDEZ DISCRIMINANTE				
Criterio de Fornell – Larcker				
Variable latente	Cartera Tecnologica	Dimension Comercial	Intermediarios	Transf_Tecn_Formal
Cartera Tecnologica	0,846			
D. Comercial	0,654	1,000		
Intermediarios	0,269	0,092	1,000	
Transferencia	0,834	0,394	0,346	0,848

In the proposed model, two constructs (Technology Portfolio and Intermediaries) jointly explain the 43.5 % of the variance of Çommercial Dimension,.ªnd the latter explains 15.6 % of the variance of the Transfer endogenous construct.

Table 12. Total effects significance test results

Source: *Authors. Note: * $p < 0,05$; ** $p < 0,10$; NS (Not significant)*

	Efecto total	Valor t	Valor p	Significancia
Cartera Tecnológica -> D. Comercial	0,678	7,137	0,000	*
Cartera Tecnológica -> Transferencia	0,267	2,707	0,007	*
D. Comercial -> Transferencia	0,394	3,828	0,000	*
Intermediarios -> D. Comercial	-0.090	0,482	0,630	NS
Intermediarios -> Transferencia	-0,035	0,353	0,724	NS

According to the results obtained and based on the relative importance of the exogenous constructs (path coefficients) that explain the technological transfer, it is observed that the Technological Portfolio is the crucial determinant in these processes, as opposed to the different types of intermediaries created to commercialize the technologies. In conclusion, the Technology Portfolio contributes significantly to the consolidation of the transfer process and has a more significant effect $(0{,}678)$.

The Technological Portfolio has a powerful total effect on the Commercial Dimension $(0{,}267)$ concerning the Total Effects. In contrast, the impact of the Intermediaries is negative $(-0{,}035)$, although the parameter was not significant.

Model proposed for the Cultural Dimension

For the model that supports the Cultural Dimension, three constructs are postulated: Characteristics of the OTRI (Carac_OTRI), Incentives, and Environment. Next, the proposed model is presented with the path coefficients and the external loads corresponding to the relationship between the constructs and their indicators.

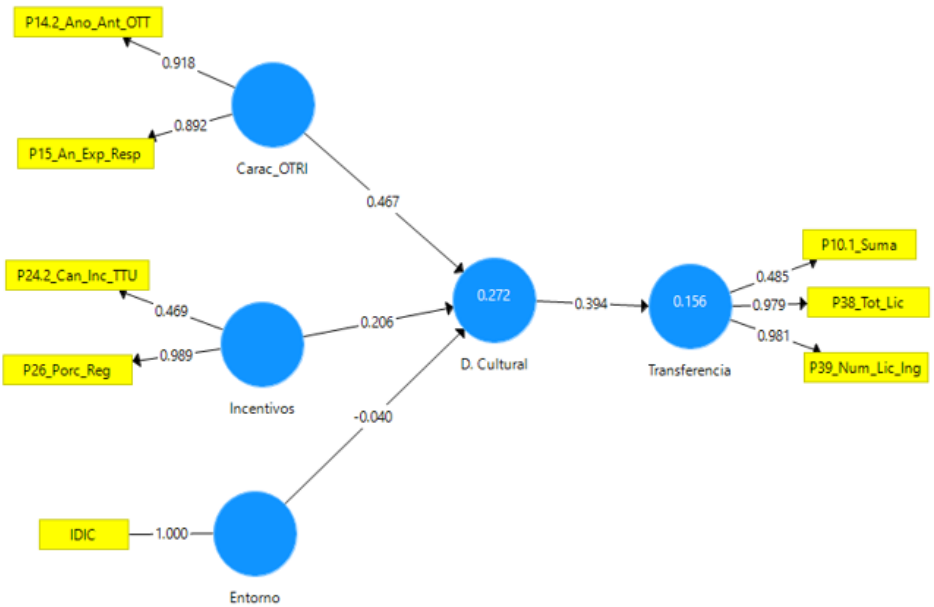

Figure 4. PLS Results proposed model Cultural Dimension

Source: *Authors*

To evaluate the model, we present the results concerning the evaluation of the individual reliability of the item, the internal consistency of the construct, the convergent validity, and the discriminant

validity. According to the results, the estimated model is reliable.

Table 13. Convergent validity and internal reliability results

Source: *Authors*

Variable latente	Indicadores	VALIDEZ CONVERGENTE		FIABILIDAD DE CONSISTENCIA INTERNA	
		Cargas (λ)	AVE	Alfa de Cronbach	Fiabilidad Compuesta
		≥ 0,40	≥ 0,50	≥ 0,60	≥ 0,60
Carac_OTRI	P14.2_Ano_Ant_OTT	0,918	0,819	0,781	0,901
	P15_An_Exp_Resp	0,892			
Incentivos	P24.2_Can_Inc_TTU	0,469	0,599	0,600	0,726
	P26_Porc_Reg	0,989			
Entorno	IDIC	1,000	1,000	1,000	1,000
Transferencia	P10.1_Suma	0,485	0,719	0,777	0,876
	P38_Tot_Lic	0,979			
	P39_Num_Lic_Ing	0,981			

Table 14. Discriminant validity

Source: *Authors*

VALIDEZ DISCRIMINANTE					
Criterio de Fornell – Larcker					
Variable latente	Carac_OTRI	Dimension Cultural	Entorno	Incentivos	Transf_Tecn_Formal
Carac_OTRI	0,905				
Dimensión Cultural	0,477	1,000			
Entorno	0,095	-0,009	1,000		
Incentivos	0,065	0,239	-0,061	0,774	
Transf_Tecn_Formal	0,240	0,394	-0,008	0,256	0,848

Since the results are different from zero, affirming that the model has predictive relevance in the latent variables analyzed (Hair *et al.,* 2014). In the model, the three constructs (Characteristics of the OTRI, Incentives, and Environment) jointly explain 27.22 % of the variance of the Çultural Dimension.ªnd, the latter, explains 15.6 % of the variance of the endogenous construct Formal Technology Transfer. According to the results (see table 15), only the parameter associated with the characteristics of the OTRI is significant in explaining the cultural dimension. The parameters associated with the environment and incentives does not define the Cultural Dimension.

Table 15. Total effects significance test results

Source: *Authors. Note: * $p < 0,05$; ** $p < 0,10$; NS (Not significant).*

	Efecto total	Valor t	Valor p	Significancia
Carac_OTRI -> D. Cultural	0,467	3,070	0,002	*
Carac_OTRI -> Transferencia	0,193	1,969	0,049	*
D. Cultural -> Transferencia	0,394	3,809	0,000	*
Entorno -> D. Cultural	-0,040	0,197	0,844	NS
Entorno -> Transferencia	-0,016	0,147	0,883	NS
Incentivos -> D. Cultural	0,206	0,622	0,534	NS
Incentivos -> Transferencia	0,081	0,458	0,647	NS

Model proposed for the Human Dimension

Two constructs explain the Human Dimension: Researchers.ªnd .ºTRI."Next, the proposed model shows the path coefficients and the corresponding external loads between the constructs and their indicators.

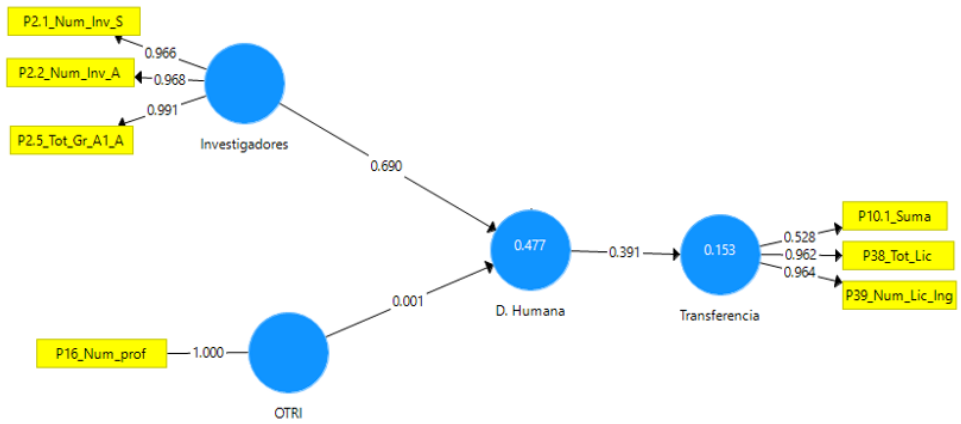

Figure 5. PLS Results proposed model Human Dimension

Source: *Authors*

The results of individual reliability, the internal consistency of the construct, the convergent validity, and the discriminant validity are presented to evaluate the model's reliability.

Table 16. Convergent validity and internal reliability results

Source: *Authors*

Variable latente	Indicadores	VALIDEZ CONVERGENTE		FIABILIDAD DE CONSISTENCIA INTERNA	
		Cargas (λ)	AVE	Alfa de Cronbach	Fiabilidad Compuesta
		≥ 0,40	≥ 0,50	≥ 0,60	≥ 0,60
Investigadores	P2.1_Num_Inv_S	0,966	0,950	0,974	0,983
	P2.2_Num_Inv_A	0,968			
	P2.5_Tot_Gr_A1_A	0,991			
OTRI	P16_Num_prof	1,000	1,000	1,000	1,000
Transf_Tecn_Formal	P10.1_Suma	0,528	0,711	0,766	0,874
	P38_Tot_Lic	0,962			
	P39_Num_Lic_Ing	0,964			

Table 17. Discriminant validity

Source: *Authors*

VALIDEZ DISCRIMINANTE				
Criterio de Fornell – Larcker				
Variable latente	Dimension Humana	Investigadores	OTRI	Transf_Tecn_Formal
Dimension Humana	1,000			
Investigadores	0,691	0,975		
OTRI	0,309	0,445	1,000	
Transf_Tecn_Formal	0,391	0,800	0,355	0,843

The R^2 values of the endogenous latent variables are in the following table. In the proposed model, the two constructs (Researchers and OTRI) jointly explain 47.7 % of the variance of the Human Dimension, and the latter explains 15.3 % of the variance of the construct endogenous called Formal Technology Transfer.

According to the results, only the Researchers are significant to the Human Dimension, while the coefficient associated with the OTRI was not significant. In addition, the coefficient associated with the Human Dimension mainly explains the transfer.

Table 18. Total effects significance test results

Source: *Authors. Note: * $p < 0,05$; ** $p < 0,10$; NS (Not significant).*

	Efecto total	Valor t	Valor p	Significancia
D.Humana -> Transferencia	0,391	3,841	0,000	*
Investigadores -> D. Humana	0,690	5,277	0,000	*
investigadores -> Transferencia	0,270	2,578	0,000	*
OTRI -> D. Humana	0,001	0,007	0,955	NS
OTRI -> Transferencia	0,000	0,005	0,996	NS

In the study, the number of Senior and Associate Researchers and the number of research groups (Researchers) have greater importance with a value of 0.690 than the number of professionals attached to the transfer units (OTRI), which has a value of 0.001. The above is consistent with the results obtained and based on the relative importance of the exogenous constructs (path coefficients) that explain technology transfer. In fact, in the Total Effects, it is observed that the Investigators have the most substantial total effect on the Human Dimension $(0{,}270)$ since the OTRIs have an impact equal to zero.

5. DISCUSSIONS

In the case of the Financial Dimension, it found that obtaining private financial resources is an essential factor for technology transfer. Similar results are reported by (O'Shea *et al.*, 2005), (Link & Siegel, 2005), and (O'Shea *et al.*, 2007). Second, public resources stand out as levers of transfer processes, as (Lach & Schankerman, 2004), (O'Shea *et al.*, 2005) and (Chang *et al.*, 2006). Finally, the allocation of resources of the universities for research and development processes and the expenses associated with the protection of intellectual property was not significant, contrary to what was stated by (Chang *et al.*, 2006), (Chapple *et al.*, 2005) and (Lockett & Wright, 2005).

Regarding the Commercial Dimension, the study shows that having a technological portfolio made up of: the number of invention disclosures (Chapple *et al.*, 2005); (Link & Siegel, 2005); (Siegel *et al.*, 2003) and the patent portfolio (Lichtenthaler & Ernst, 2010), is a significant component for technology transfer processes. On the other hand, having intermediaries (TTO and Incubators) as defined organizational structures within the university was not substantial, in contrast with previous studies on

the importance of incubators (Lichtenthaler & Ernst, 2010) or the transfer units (Mian, 1996); (O'Shea *et al.*, 2005); (Mathews & Hu, 2007). For this reason, the results indicate that Colombian universities should define invention disclosure processes and focus on having an established technological portfolio to facilitate their formal technology transfer processes.

About the Cultural Dimension, the study showed that the time transfer activities take and the years of experience of those responsible for carrying out the transfer processes are important variables to explain technology transfer. A similar result is reported by (Link & Siegel, 2005), (Chapple *et al.*, 2005) and (Lockett & Wright, 2005).

Incentives can be configured in structures that facilitate or hinder transfer processes, according to (Stezano, 2011). Despite its importance, the results related to the number of incentives show no statistical significance of these aspects in the formal transfer processes in Colombian universities. The incidence of the environment in the university-company transfer processes was not statistically significant either. This result thus constitutes a contribution of the present work to the literature.

For the Human Dimension, the relevance of human capital made up of the number of quality researchers (Senior and Associates) and the number of research groups (A1 and A) can be evidenced as the main determinants of formal transfer processes. These results have also been reported in the literature by authors like (Foltz *et al.*, 2000), (Friedman & Silberman, 2003) and (Lach & Schankerman, 2004). In contrast, the number of professionals dedicated to transfer activities was not significant.

6. CONCLUSIONS

Technology transfer seeks to expand innovative knowledge and new technologies in companies through formal and informal channels. Due to its importance, several studies have sought to establish the main factors that determine the dynamics of this transfer in the universities of developed countries. However, little has been explored in the context of emerging economies, and studies in the Colombian case are scarce. This work took a sample of data from Colombian universities. It integrated the technique of structural equations to identify the most critical factors of the transfer and made the following findings.

First, the significance of the financial, cultural, commercial, and human dimensions in the processes of technology transfer is confirmed theoretically and empirically. The results obtained show, in the

financial dimension, the importance of external financial resources (public and private) in the formal transfer processes, while own resources allocated to R&D were not significant. The foregoing could be linked to the fact that, in the majority of calls for the allocation of external resources, specific results are requested as a result of previous needs, whether from public or private organizations, while the internal resources allocated to R&D may not necessarily be due to needs of the environment and are subject to the institutional interests of the universities.

Concerning the commercial dimension, the study makes it possible to show that a statistically significant component is having a technological portfolio, which is the product of both the number of invention disclosures selected to be protected and the patent portfolio (filed before the SIC and the PCT) that the institution has. The important thing is that this technological portfolio must obey previous technical surveillance to identify potential clients interested in the technologies produced by the university and a series of capacities that allow the effective development of business. It should be noted that approximately half of the universities in the sample consider that they have an average level in aspects related to the ability to develop businesses, skills to negotiate with clients, and skills to detect and contract venture capital and seed funds. On the other hand, it was not significant in the study to have organizational structures created as intermediaries in the transfer processes, such as incubators or research results transfer offices.

The study also shows that, regarding the cultural dimension, the statistically significant determinants are associated with the time transfer activities carried out in the institution and the experience of those responsible for these processes. These criteria show that intermediaries in formal transfer processes are not necessary. The relevant thing is to have an entrepreneurial tradition and to have as a criterion the experience of those in charge of said processes. On the other hand, the number of incentives offered to teachers who are immersed in research and transfer activities was not significant, which invites Colombian university institutions to reflect on what could be the motivational factors that facilitate learning processes transfer. Another important finding of the study is that there was no incidence of the environment in the university-business transfer processes, which suggests a lack of articulation between the different actors that are part of the innovation ecosystem.

Regarding the human dimension, the relevance of concentrated human capital in the Colombian case to Senior and Associate researchers according to the Minciencias classification and the number of

A1 and A type research groups was evidenced. The preceding shows the importance of human resources as an agent that generates inventions; for this reason, it is necessary to strategically align this resource to the needs of society to achieve successful technology transfer processes that contribute to the environment and impact the development of the country. In contrast, the number of professionals dedicated to transfer activities was not significant, a result that goes along the same path as the non-significance of organizational structures in charge of transfer processes.

In short, the evidence indicates that the main factors to improve university technology transfer are: the development of a technological portfolio, the hiring of personnel experienced in transfer processes, high-profile researchers, and the consolidation of research groups of the maximum quality.

FUNDING

This article is a product derived from the doctoral thesis research "Determinants of university technology transfer in Colombia based on the theory of resources and capabilities," which was completed in June 2021

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https://revistas.udistrital.edu.co/index.php/Tecnura/issue/view/1201

DOI: https://doi.org/10.14483/22487638.19956

INVESTIGACIÓN

Evaluación de un residuo de la combustión de carbón como reemplazo parcial de arena en la producción de ladrillos cerámicos

Evaluation of a coal combustion waste as a partial replacement for sand in the production of ceramic bricks

José Fernando Benítez-Vivas [1], Luisa Fernanda Mosquera-Idrobo [2], Janneth Torres-Agredo [3]

Fecha de Recepción: 12 de septiembre de 2022 **Fecha de Aceptación**: 27 de marzo de 2023

Cómo citar: Benítez-Vivas, J.F., Mosquera-Idrobo, L.F. y Torres-Agredo, J. (2023). Evaluación de un residuo de la combustión de carbón como reemplazo parcial de arena en la producción de ladrillos cerámicos. *Tecnura*, **27**(78), 103-122. https://doi.org/10.14483/22487638.19956

Abstract

Context: During the combustion of coal, large amounts of residues are generated, such as bottom ash. These have been investigated as a replacement for cement and as a substitute for sand to produce concrete. Also, this residue can be used for the manufacture of clay products.

Method: A physicochemical and mineralogical characterization of the bottom ash was carried out; furthermore, the toxicity of the residue was evaluated through the leaching test-Toxicity Characteristic Leaching Procedure and the ecotoxicity test-Daphnia pulex. Then, bricks were manufactured at the laboratory level with the addition of ash in 2 %, 4 %, 6 % and 8 % with respect to the amount of sand; the physical and mechanical properties were evaluated and environmental tests were carried out on the bricks.

Results: The results showed a reduction in compressive strength with increasing ash; however, the bricks that incorporated 4 % ash obtained a resistance of 14.16 MPa, which met the minimum criteria of compressive strength of the Colombian standard for non-structural masonry. On the other hand, the applied leaching test showed that leachable metal concentrations were below environmental regulations.

Conclusions: These findings demonstrate the feasibility of using up to 4 % coal bottom ash, as a replacement for sand in clay brick production. This will mitigate the problems associated with its removal.

Keywords: Coal, bottom ash, ecological bricks, mechanical properties.

[1]Ingeniero químico, estudiante de Maestría en ingeniería ambiental de la Universidad Nacional de Colombia. Palmira, Colombia.
Email: jbenitezv@unal.edu.co
[2]Ingeniera ambiental de la Universidad Nacional de Colombia. Palmira, Colombia.
Email: lufmosqueraid@unal.edu.co
[3]Tecnóloga Química e Ing. de Materiales, Dra. en Ingeniería con énfasis en Ingeniería de Materiales, profesora titular de la Universidad Nacional de Colombia. Palmira, Colombia.
Email: jtorresa@unal.edu.co

Resumen

Contexto: Durante la combustión de carbón se generan grandes cantidades de residuos, como las cenizas de fondo; éstas se han investigado como reemplazo del cemento y como sustituto de la arena para la producción de concreto. Además, este residuo puede ser usado para la fabricación de productos de arcilla.
Método: En este estudio, se llevó a cabo una caracterización físico-química y mineralógica de las cenizas de fondo; además, se evaluó la toxicidad del residuo a través del test de lixiviación-Procedimiento de Lixiviación Característico de Toxicidad y del ensayo de ecotoxidad-Daphnia pulex. Seguidamente, se fabricaron ladrillos a nivel de laboratorio con adición de cenizas en 2 %, 4 %, 6 % y 8 % con respecto a la cantidad de arena; se evaluaron propiedades físicas y mecánicas y, se realizaron ensayos ambientales a los ladrillos.
Resultados: Los resultados mostraron una reducción de la resistencia a la compresión con el aumento de cenizas; sin embargo, los ladrillos que incorporaron cenizas al 4 % obtuvieron una resistencia de 14,16 MPa el cual cumple con los criterios mínimos de resistencia a la compresión de acuerdo con la norma colombiana para mampostería no estructural. Por otra parte, el ensayo de lixiviación aplicado mostró que las concentraciones de metales lixiviables estaban por debajo de las regulaciones ambientales.
Conclusiones: Estos hallazgos demuestran la viabilidad de utilizar hasta un 4 % de cenizas de fondo de carbón como reemplazante de arena en la producción de ladrillos de arcilla. El cual permitirá mitigar los problemas asociados a su eliminación.

Palabras clave: Carbón, cenizas de fondo, ladrillos ecológicos, propiedades mecánicas.

1. Introducción

En los últimos años, se ha promovido el uso de energías renovables, sin embargo, la industria del carbón continúa siendo un sector importante del suministro de energía en el mundo (Rodríguez-Álvaro, R., González-Fonteboa, B., Seara-Paz, S., & Rey-Bouzón, E. J. (2021)), (Zhou, H., Bhattarai, R., Li, Y., Si, B., Dong, X., Wang, T., & Yao, Z. (2021)). Se estima que para el 2030, el 47 % del abastecimiento eléctrico mundial se generará de plantas térmicas a base de carbón (Ankur, N., & Singh, N. (2021)). Durante la combustión de carbón se generan grandes cantidades de residuos, como cenizas de fondo, cenizas volantes, escorias y materiales de la desulfuración de gases de combustión (Rodríguez-Álvaro, R., González-Fonteboa, B., Seara-Paz, S., & Rey-Bouzón, E. J. (2021)). Las cenizas de fondo (CFC), son partículas pesadas que caen al piso y representan entre el 15-25 % del total de las cenizas de carbón producidas (Ankur, N., & Singh, N. (2021)). Las CFC están compuestas principalmente por óxidos de sílice, aluminio, hierro y calcio, estas dos últimas en menor proporción; dicha composición puede variar dependiendo de la fuente de carbón. Su composición mineralógica consiste básicamente en cuarzo, mullita y en menores proporciones cristobalita, hematita y magnetita. También presenta

una gran cantidad de fases amorfas (Da Fonseca, B. S., Galhano, C., & Seixas, D. (2015)). La literatura además reporta un tamaño de partícula entre 63 micras a 10 mm (Singh, M. (2018)), (Hashemi, S. S. G., Mahmud, H. B., Ghuan, T. C., Chin, A. B., Kuenzel, C., & Ranjbar, N. (2019)). Debido a la presencia de metales pesados tales como arsénico, cromo, boro, vanadio y antimonio, las cenizas de carbón han sido consideradas por algunos autores como residuos peligrosos; además porque éstos pueden lixiviar y contaminar suelos y aguas (Sushil, S., & Batra, V. S. (2006)) y (Rai, U. N., Pandey, K., Sinha, S., Singh, A., Saxena, R., & Gupta, D. K. (2004)). En el estudio llevado a cabo por (Sushil, S., & Batra, V. S. (2006)), encontraron la presencia de metales tales como Cr, Pb, Mn, Zn, Cu, Ni y Co, tanto en cenizas volantes como en cenizas fondo. Sin embargo, los autores reportaron mayores concentraciones de estos metales en las cenizas volantes, lo cual lo atribuyen a la diferencia de masa que hay entre los metales; estos valores también pueden variar de una planta a otra y entre países. Por otra parte, (Hashemi, S. S. G., Mahmud, H. B., Ghuan, T. C., Chin, A. B., Kuenzel, C., & Ranjbar, N. (2019)), utilizaron el método de solidificación/estabilización para reducir la lixiviación de metales presentes en las CFC; para llevar a cabo el proceso realizaron mezclas de CFC con Cemento Portland (CEM I). Las cenizas evaluadas presentaban iones de Cd, Cu, Ni y Pb que sobrepasaban los estándares de toxicidad de Malasia. Los autores encontraron que todos los elementos se lograron inmovilizar con éxito, incluso cuando las mezclas presentaban un bajo contenido de cemento. Vale la pena mencionar, que los estudios de lixiviación de metales en las CFC son escasos, básicamente se han realizado estudios de lixiviación en las cenizas volantes de carbón. Por otra parte, en los últimos años se han investigado las CFC como reemplazo del cemento y como sustituto de la arena para la producción de concreto (Kim, H. K., & Lee, H. K. (2011)), (Aydin, E. (2016)), (Rafieizonooz, M., Mirza, J., Salim, M. R., Hussin, M. W., & Khankhaje, E. (2016)), (Singh, M., & Siddique, R. (2016)) y (Argiz, C., Moragues, A., & Menéndez, E. (2018)). También, desde el punto de vista teórico, de acuerdo con la composición química y mineralógica, este residuo puede ser usado para la fabricación de productos de arcilla (Da Fonseca, B. S., Galhano, C., & Seixas, D. (2015)). (Naganathan, S., Mohamed, A. Y. O., & Mustapha, K. N. (2015)) evaluaron el desempeño de ladrillos elaborados con cemento, cenizas volantes y cenizas de fondo de carbón. En los ladrillos obtenidos la resistencia a la compresión osciló entre 7,13 y 17,36 MPa, resistencias que se encuentran dentro de los límites para los ladrillos convencionales. También, se reportó que los ladrillos presentaron una durabilidad mayor comparada con los ladrillos de arci-

lla. Finalmente, concluyen que las cenizas volantes y cenizas de fondo presentan un gran potencial para ser utilizados como materia prima en la producción de ladrillos. Por su parte, (Alhokabi, A. A., & Ing, D. S. (2019)) investigaron el reemplazo parcial de arena por cenizas de fondo de carbón en la producción de ladrillos. Para el proceso de fabricación se estudió la sustitución del cemento portland ordinario por cenizas volantes en un 20 % y, reemplazos de arena del 5 %, 10 %, 15 % y 20 % por las CFC. Los resultados mostraron que la resistencia a la compresión y la resistencia a la flexión más alta se presentó para las mezclas que incorporaron cenizas de fondo al 5 %, pero fueron menores en comparación con la muestra control. Los autores mencionan que las cenizas de carbón pueden ser utilizadas en la elaboración materiales de construcción, para el remplazo de agregados naturales. Vale la pena mencionar, que la posibilidad de darles diversos usos a las cenizas de carbón a nivel industrial tiene una importante relevancia ambiental y económica, que se traduce en la disminución del uso de terrenos y costos de disposición, además que se impulsa la economía local (Spadoni, M., Voltaggio, M., Sacchi, E., Sanam, R., Pujari, P. R., Padmakar, C., & Wate, S. R. (2014)). Por lo tanto, el presente trabajo, tiene como objetivo estudiar y evaluar las cenizas de fondo de carbón (CFC) como materia prima para la fabricación de ladrillos de arcilla. Con esto se lograría no sólo su valorización, sino también la prevención de los impactos ambientales causados por su disposición final. Este estudio está orientado en el concepto de desarrollo sostenible, puesto que se pretende contribuir a las soluciones de los problemas de reducción de áridos naturales y reducción de tierras por disposición de residuos. El cual apunta al objetivo del desarrollo sostenible (Naciones Unidas (2015)): ODS 12 “Garantizar modalidades de consumo y producción sostenibles”, con el fin de lograr la gestión sostenible y el uso eficiente de los recursos naturales y, reducir considerablemente la generación de desechos mediante actividades de prevención, reducción, reciclado y reutilización.

2. METODOLOGÍA

Caracterización de las cenizas de fondo de carbón

Las cenizas de fondo de carbón (CFC), objeto de estudio, fueron suministradas por una industria colombiana. Se seleccionaron cuatro muestras, las cuales se denominaron CFC1, CFC2, CFC3 y CFC4. Las cenizas se tomaron en diferentes tiempos de producción. Se evaluó la composición química, mi-

neralógica y morfológica de las cenizas, mediante las técnicas de fluorescencia de rayos X, difracción de rayos X y microscopia electrónica de barrido (SEM), respectivamente. Así mismo, se determinó la distribución de tamaño de partícula por la técnica de granulometría láser y se evaluó la pérdida al fuego de las muestras. El análisis químico se determinó utilizando un espectrómetro de fluorescencia de rayos X MagisPro PW-2440 Philips (WDXRF) equipado con un tubo de Rodio, con una potencia máxima de 4 KW. El análisis semicuantitativo se realizó con el software SemiQ5, haciendo 11 barridos, con el fin de detectar todos los elementos presentes en la muestra, excluyendo H, C, Li, Be, B, N, O y los elementos transuránicos.

La composición mineralógica se obtuvo en un difractómetro de rayos X marca PANalytical, modelo EMPYREN, la muestra fue medida en una configuración óptica Bragg-Brentano con un detector de estado sólido de alta velocidad para la adquisición de datos, denominado PIXCEL.

La morfología de las cenizas se analizó por Microscopía electrónica de Barrido (SEM), utilizando un equipo marco JEOL (JSM 5910 LV), operada a un voltaje de aceleración de 20 Kv, las imágenes se obtuvieron a un aumento de 100. Además, se realizó el análisis de composición química utilizando un espectrómetro de dispersión de energía de rayos X (EDS).

Fabricación de ladrillos a nivel de laboratorio

Las materias primas utilizadas para la fabricación de ladrillos fueron arcilla, chamote (ladrillo molido), arena y ceniza de fondo; para esta última se seleccionó un solo tipo de ceniza (CFC3). En la Tabla 1, se muestra la proporción de la materia prima utilizada para la elaboración de los ladrillos adicionados con la ceniza como reemplazo de arena. Los ladrillos fueron fabricados a nivel de laboratorio (ver Figura 1). En el proceso de fabricación de ladrillos, las materias primas se mezclaron mecánicamente, la cantidad de agua añadida se ajustó hasta obtener una consistencia maleable; posteriormente, los ladrillos se secaron a temperatura ambiente por un día; después se ingresaron a un horno microondas a 190°C por 24 horas. Finalmente, los ladrillos pasaron por un horno túnel por 24 horas, a una temperatura de 850°C. Este último paso se realizó en el horno de la empresa que suministró el residuo para el presente estudio.

Tabla 1. Composición de la materia prima para la elaboración de los ladrillos.

Fuente: Autores.

Tipo de Ladrillo	Arcilla (%)	CFC3 (%)	Chamote (%)	Arena (%)
F0 (control)	75	0	12,5	12,5
F2	75	2	12,5	10,5
F4	75	4	12,5	8,5
F6	75	6	12,5	6,5
F8	75	8	12,5	5,5

Figura 1. Ladrillos fabricados con adición de cenizas de fondo

Fuente: Autores.

Se llevaron a cabo los ensayos de porosidad aparente, densidad aparente y gravedad específica de acuerdo con la norma ASTM C20: 2010. La resistencia a la compresión y absorción de agua se aplicó siguiendo los lineamientos de la NTC 4017:2015. También, se determinó la pérdida de peso y contracción lineal a las muestras de ladrillos.

Por último, considerando que posiblemente las cenizas estudiadas sean un residuo peligroso, se evaluó la toxicidad del residuo (CFC3) a través del test de lixiviación-Procedimiento de Lixiviación Característico de Toxicidad (TCLP por sus siglas en inglés) (EPA SW-846 Método 1311). Así mismo, a los ladrillos producidos a nivel de laboratorio se les realizaron los ensayos ambientales y el ensayo de

toxicidad aguda para Daphnia Pulex siguiendo el protocolo 6,3 del IDEAM (Resolución 002 de2007); con el fin de verificar su condición de producto no peligroso.

3. RESULTADOS Y DISCUSIÓN

Características de las cenizas de fondo de carbón

En la Tabla 2, se presenta las características químicas de las cenizas de fondo de carbón; donde se observa que las CFC evaluadas tienen composiciones similares. El contenido de SiO_2 en las cenizas está entre 59,04 % y 63,12 %, siendo éste su componente principal; seguido de otros óxidos como Al_2O_3, Fe_2O_3, SO_3 y CaO. Las CFC evaluadas presentan composiciones químicas similares a lo reportado por (Sutcu, M., Erdogmus, E., Gencel, O., Gholampour, A., Atan, E., & Ozbakkaloglu, T. (2019)), donde se evalúa las CFC como materia prima para la elaboración de ladrillos de arcilla. Además, la pérdida al fuego de las cenizas estuvo entre 13,28 % y 30,62 %; siendo CFC3 la que presentó el más alto porcentaje.

Por otra parte, es importante mencionar que las cenizas presentan en su composición metales como Cr, V, Ba, Pb que pueden lixiviar al ambiente (Sushil, S., & Batra, V. S. (2006)) y, por lo tanto, afectar su aprovechamiento como material de construcción. Por tal motivo, se realizaron ensayos de lixiviación y de ecotoxicidad al residuo; los cuales se presentarán más adelante.

Tabla 2. Composición química de las cenizas de fondo de carbón.

Fuente: Autores.

Características	CFC1	CFC2	CFC3	CFC4
SiO_2	59,04	63,12	59,86	60,66
Al_2O_3	22,00	24,15	24,24	24,98
Fe_2O_3	8,64	4,76	7,16	6,30
SO_3	3,80	1,58	2,76	2,19
CaO	1,77	1,85	1,39	1,42
TiO_2	1,32	1,30	1,30	1,29
P_2O_5	1,12	1,05	1,01	1,04
K_2O	0,92	0,82	1,11	0,94
Na_2O	0,41	0,47	0,38	0,39
MgO	0,35	0,39	0,33	0,32
Cr	0,18	0,02	0,03	0,06
Ba	0,13	0,15	0,15	0,15
MnO	0,03	0,02	0,01	0,01
V	0,02	0,03	0,02	0,02
Cu	0,01	0,02	0,02	94 ppm
Pb	0,01	97 ppm	-	0,01
Zn	76 ppm	51 ppm	46 ppm	55 ppm
Se	-	28 ppm	-	-
Sr	0,11	0,10	0,12	0,11
Ce	0,06	0,09	0,04	0,04
Y	81 ppm	57 ppm	60 ppm	54 ppm
Pérdida al fuego (%)	22,81	16,65	30,62	13,28

En la Figura 2, se presenta el difractograma de rayos X para la muestra CFC3. Se observa que la ceniza tiene una estructura parcialmente amorfa, debido al levantamiento de la línea base; además,

presenta fases cristalinas como Cuarzo (SiO_2), Hematita (Fe_2O_3) y Anatasa (TiO_2). La cuantificación de las fases cristalinas y fase amorfa de las cenizas se presentan en la Tabla 3; donde se observa que el principal constituyente de las cenizas es el cuarzo (58,7 %), seguido de la fase amorfa (23,2 %). Debido a esto, la ceniza de fondo del estudio se puede considerar como un material desgrasante, debido al alto contenido de Cuarzo (Afanador García, N., Ibarra Jaime, A. C., & López Durán, C. A. (2013)). Estos resultados son consistentes con la composición química de las cenizas (ver Tabla 2).

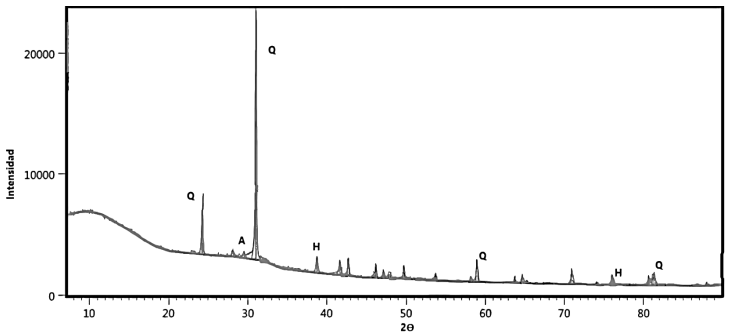


Figura 2. Difractograma de CFC3. Q-Cuarzo; H-Hematita; A-Anatasa.

Fuente: Autores.

Tabla 3. Cuantificación de las fases cristalina y fase amorfa de las cenizas de fondo.

Fuente: Autores.

Fases	Fórmula química	CFC3 (%)
Cuarzo	SiO_2	58,7
Hematita	Fe_2O_3	15,9
Anatasa	TiO_2	2,2
Amorfos	-	23,2

Teniendo en cuenta los anteriores resultados, se puede afirmar que las cenizas de fondo de carbón estudiadas presentan un gran potencial para ser aprovechadas como materia prima secundaria en la fabricación de ladrillos de arcilla, debido a su composición química y mineralógica (Torres, J., Mosquera, L. F., Paz, P., and Díaz, M. F. (2021)).

En cuanto a las características físicas, la distribución de tamaño de partícula se muestra en la Figura 3.

La ceniza presentó un tamaño de partícula medio de 166 µm. Por otra parte, es importante mencionar que la arena utilizada para este estudio presentó un tamaño de partícula de aproximadamente 200 µm.

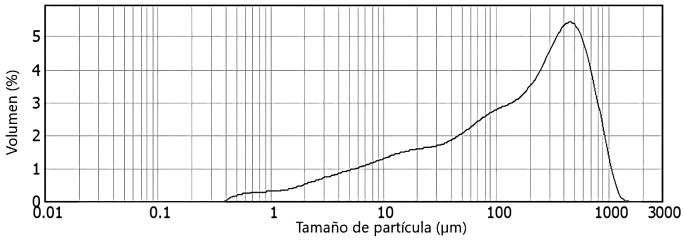
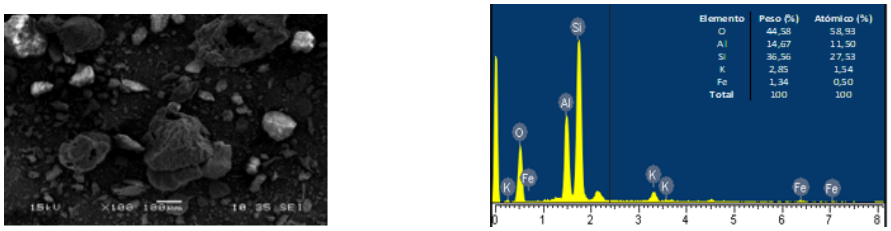


Figura 3. Distribución de tamaño de partícula de CFC3.

Fuente: Autores.

En la Figura 4, se presenta la morfología de la muestra CFC3. Se observan partículas angulares irregulares de diferentes tamaños, lo que confirma la distribución de partícula (Figura 3); además, las CFC presentan algunas partículas porosas. Por otra parte, el análisis EDS muestra que las cenizas presentan SiO_2 como componente principal, seguido de Al_2O_3. Estos resultados ratifican lo obtenido en el análisis de FRX y DRX.



(a) **(b)**

Figura 4. (a) Imagen SEM y (b) patrón EDS de CFC3

Fuente: Autores.

Evaluación de los ladrillos cerámicos

En la Tabla 4, se presentan los resultados de absorción de agua, porosidad aparente, densidad aparente, gravedad especifica aparente y pérdida de peso de los ladrillos fabricados con CFC y del ladrillo control.

La durabilidad de los ladrillos depende en gran medida de la absorción de agua; donde una alta

absorción de agua puede generar grietas en los cuerpos cerámicos y, por lo tanto, disminuir su durabilidad (Hasan, M. R., Siddika, A., Akanda, M. P. A., & Islam, M. R. (2021)). La absorción de agua en las muestras de ladrillos presentó un ligero incremento con el aumento en la proporción de las cenizas. Los ladrillos que incorporaron CFC3 al 8 % presentaron la absorción más alta, con un porcentaje del 22,6 %, en comparación con los ladrillos control (16,77 %); lo que resultó en un aumento de aproximadamente del 35 %. Estudios de otros autores, reportan un aumento en la absorción de agua de ladrillos de arcilla que incorporan residuos (Sutcu, M., Erdogmus, E., Gencel, O., Gholampour, A., Atan, E., & Ozbakkaloglu, T. (2019)).

Así mismo, la porosidad es un parámetro importante para determinar la calidad y el rendimiento de los ladrillos (Hasan, M. R., Siddika, A., Akanda, M. P. A., & Islam, M. R. (2021)). Como se observa en la Tabla 4, la porosidad aparente de las muestras de ladrillos aumentó con la adición de cenizas. Esto es consistente con estudios anteriores que reportaron un aumento de la porosidad aparente de ladrillos con la adición de residuos (Tjaronge, M. W., & Caronge, M. A. (2021)). La porosidad más alta se presentó para el ladrillo F8 con un valor del 38,17 %, con relación a la muestra control que presentó una porosidad del 32,93 %. Por otro lado, la muestra de ladrillo F4 presentó una porosidad similar a la muestra control, con un valor del 33,76 %. El incremento de la porosidad aparente en las muestras de ladrillos con CFC puede estar relacionada con el alto porcentaje de pérdida al fuego de la ceniza CFC3, la cual fue del 30,62 % (Kazmi, S. M., Abbas, S., Saleem, M. A., Munir, M. J., & Khitab, A. (2016)).

La densidad aparente disminuyó con el aumento de cenizas en las muestras de ladrillos. La densidad disminuyó de 1,70 g/cm^3 (ladrillo control) hasta un 1,51 g/cm^3 (ladrillo F8), lo que representa una reducción del 11 %. Estas observaciones son similares a lo reportado por (Djamaluddin, A. R., Caronge, M. A., Tjaronge, M. W., & Irmawaty, R. (2020)). Por otra parte, la incorporación de cenizas generó una disminución en la gravedad especifica de los ladrillos; excepto para los ladrillos F2; la gravedad especifica más bajas se presentó para la muestra F8, con un valor de 2,44; comparada con la muestra control que obtuvo una gravedad especifica de 2,54.

Por último, en la Tabla 4, se presenta la pérdida de peso de los ladrillos, durante el proceso de cocción. La adición de cenizas aumentó los valores de pérdida de peso de los ladrillos en comparación con la muestra control, siendo el máximo del 6,35 % para la muestra F8; lo que se puede atribuir al

alto valor de pérdida al fuego de CFC3.

Tabla 4. Propiedades de las muestras de ladrillos adicionados con CFC.

Fuente: Autores.

Tipo de ladrillo	Absorción de agua (%)	Porosidad aparente (%)	Densidad aparente (g/cm3)	Gravedad especifica aparente	Pérdida de peso (%)
F0	16,77	32,93	1,70	2,54	4,12
F2	20,91	36,68	1,61	2,54	5,02
F4	18,53	33,76	1,65	2,48	5,16
F6	21,61	37,83	1,53	2,47	5,35
F8	22,06	38,17	1,51	2,44	6,35

La contracción lineal de las muestras de ladrillos se presenta en la Figura 5; dicha contracción se genera por la pérdida de agua durante el proceso de combustión. Vale la pena mencionar que la contracción excesiva puede causar microgrietas dentro de los ladrillos (Hasan, M. R., Siddika, A., Akanda, M. P. A., & Islam, M. R. (2021)). Se observa que la contracción de los ladrillos disminuyó con el aumento de cenizas. La contracción lineal del ladrillo control fue del 7,4 %; mientras que los ladrillos con cenizas se contrajeron hasta un 5,75 %. Se establecen límites de contracción para ladrillos de buena calidad por debajo del 8 % (Hasan, M. R., Siddika, A., Akanda, M. P. A., & Islam, M. R. (2021)), por lo que todos los ladrillos elaborados con cenizas cumplen con este parámetro. Estudios de otros autores, reportan que la contracción disminuye con la incorporación de residuos en ladrillos de arcilla (Tjaronge, M. W., & Caronge, M. A. (2021)) y (Hasan, M. R., Siddika, A., Akanda, M. P. A., & Islam, M. R. (2021)). Por otra parte, es importante mencionar que los ladrillos no presentaron deformaciones durante el proceso de cocción.

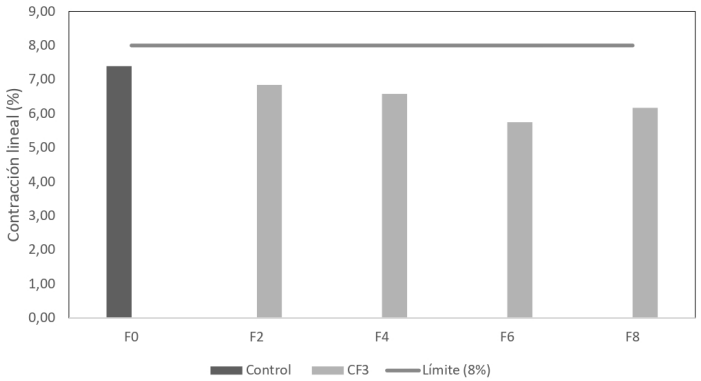


Figura 5. Contracción lineal de los ladrillos.

Fuente: Autores.

La propiedad más importante para determinar la calidad de los ladrillos es la resistencia a la compresión (Hasan, M. R., Siddika, A., Akanda, M. P. A., & Islam, M. R. (2021)). En la Figura 6, se muestra la resistencia a la compresión de los ladrillos; donde se observa que la resistencia disminuyó con la incorporación de cenizas. La muestra de ladrillo F4 (14,16 MPa) presentó una resistencia a la compresión similar a la muestra control (14,61 MPa), mientras que la muestra F8 (10,40 MPa) exhibió la resistencia a la compresión más baja en relación con la muestra control. La norma técnica colombiana NTC 4205-2:2019, para mampostería no estructural - ladrillos macizos, establece que la resistencia a la compresión promedio de 5 unidades debe ser mínimo de 14 MPa. Por lo tanto, los ladrillos que incorporaron CFC3 al 4 % cumplen con este requisito. La reducción de la resistencia a la compresión se ha reportado en otros estudios que incorporan residuos en la fabricación de ladrillos de arcilla (Tjaronge, M. W., & Caronge, M. A. (2021)).

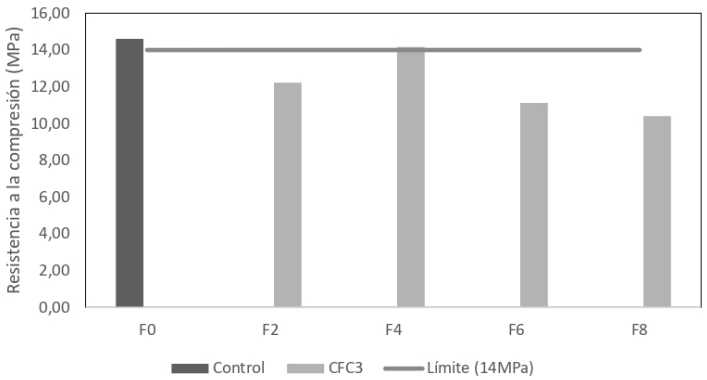


Figura 6. Resistencia a la compresión de los ladrillos .

Fuente: Autores.

Estos hallazgos indican que el reemplazo del 4 % de arena con cenizas de fondo de carbón, se obtienen ladrillos que cumplen con los estándares establecido por la normatividad colombiana para la elaboración de ladrillos de arcilla para mampostería no estructural.

Caracterización ambiental

Durante la combustión de carbón, metales como Cd, Pb, Cr, Pb, Co presentes en el carbón se distribuyen en las cenizas volantes y cenizas de fondo (Saha, D., Roychowdhury, T., Chatterjee, D., & Joseph, A. (2022)). La concentración de estos metales depende de las condiciones de combustión, propiedades físicas y químicas del metal; la eficiencia del proceso de recolección también afecta la concentración de estos metales en las cenizas (Singh, M. (2018)). La liberación de estos metales pueden ser una fuente potencial de contaminación de aguas superficiales y subterráneas (Saha, D., Roychowdhury, T., Chatterjee, D., & Joseph, A. (2022)).

En la Tabla 5, se presentan los resultados obtenidos de la prueba de lixiviación-Procedimiento de Lixiviación Característico de Toxicidad (TCLP) para la ceniza CFC3 y la muestra de ladrillo F4. Se seleccionó el ladrillo F4, dado que, éste presentó la mejor resistencia a la compresión según la norma colombiana para mampostería no estructural. De acuerdo a los resultados, se encontró que los metales lixiviables evaluados se encuentran por debajo de lo establecido en el Decreto 4741 de 2005 (Ministerio de Ambiente, Vivienda y Desarrollo Territorial (2005)), para residuos peligrosos. Según lo anterior, las cenizas de fondo de carbón del presente estudio pueden ser consideradas como un resi-

duo no peligroso.

Tabla 5. Lixiviación de metales para CFC3 y ladrillo F4.

Fuente: Autores.

TCLP (mg/L)	CFC3	Ladrillo F4	Nivel máximo permisible (mg/L)*
As	0,0412	0,00396	5
Ba	<0,5	<0,5	100
Cd	<0,01	<0,01	1
Cr	<0,1	<0,1	5
Hg	<0,001	<0,001	0,2
Ag	<0,05	<0,05	5
Pb	<0,1	<0,1	5
Se	<0,0025	<0,0025	1
Zn	0,0645	<0,05	-

*Límite máximo establecido en la legislación colombiana para residuos peligrosos.

En el ladrillo, la lixiviación de metales también fue menor que las concentraciones límites. Se observa que la lixiviación de metales como As y Zn en el ladrillo fue inferior comparado con la lixiviación de las cenizas. Se puede decir que se presentó una inmovilización de estos metales en el material cerámico. Es importante mencionar que el porcentaje de reemplazo de cenizas en las muestras de ladrillos es relativamente bajo. Estos resultados coinciden con lo reportado por (Sutcu, M., Erdogmus, E., Gencel, O., Gholampour, A., Atan, E., & Ozbakkaloglu, T. (2019)), donde evaluaron la lixiviación de metales como As, Ba, Cd, Cr, Cu, Pb en ladrillos que incorporaban cenizas de fondo de carbón, encontrando que las concentraciones de lixiviación de los ladrillos estaban por debajo de las concentraciones limites establecido por la EPA para residuos peligrosos. Por otra parte, el ensayo de toxicidad aguda para Daphnia Pulex de los ladrillos F4 presentó un porcentaje de inmovilización del 25 %, el cual indica un bajo efecto tóxico en los organismos de prueba. Finalmente, estos resultados demuestran que la producción de ladrillos con CFC es seguro.

De acuerdo con los resultados obtenidos, las cenizas de fondo de carbón se pueden utilizar como

materia prima secundaria en la producción de ladrillos de arcilla; cumpliendo con las normas colombianas para la elaboración de ladrillos de arcilla para mampostería no estructural. Por otra parte, los ensayos ambientales realizados a los ladrillos indican que son un producto no peligroso. El aprovechamiento de residuos como las cenizas de fondo en materiales de construcción, permitirá reducir la cantidad de áridos naturales y mitigar los problemas asociados a la a su disposición final. Finalmente, se recomienda continuar con el estudio de tal manera que se pueda escalar a nivel industrial.

4. CONCLUSIONES

Del presente estudio realizado a nivel de laboratorio, sobre el reemplazo parcial de arena por cenizas de fondo en la fabricación de ladrillos, se concluye que:

Las cenizas de fondo de carbón se componen principalmente de óxidos de sílice, aluminio y en menor proporción hierro. En cuanto a su composición mineralógica, las cenizas presentan un alto contenido de cuarzo y amorfos.

Con la evaluación del desempeño de los ladrillos, se encontró que la absorción de agua y la porosidad aparente aumentaron con la incorporación de cenizas. Mientras que, la densidad aparente de las muestras de ladrillos disminuyó.

Los ladrillos que incorporaron cenizas al 4 % presentaron una resistencia a la compresión de 14,16 MPa, los cuales se pueden utilizar para mampostería no estructural de acuerdo con la norma técnica colombiana.

Los ensayos ambientales indican que las cenizas de fondo de carbón y los ladrillos con CFC son productos no peligrosos. Los resultados mostraron una inmovilización de los metales en la matriz cerámica.

Estos hallazgos demuestran la viabilidad de utilizar hasta un 4 % de cenizas de fondo de carbón como reemplazante de arena en la producción de ladrillos de arcilla. El cual permitirá dar solución a los problemas de disposición de estos residuos y, además, reducirá la cantidad de áridos naturales utilizados para estos procesos.

FINANCIAMIENTO

Este estudio fue financiando por la Universidad Nacional de Colombia en el marco de la convocatoria "Proyectos para el fortalecimiento de la investigación y la innovación de la Universidad Nacional de Colombia - Sede Palmira 2019-2021"

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Tecnura

https://revistas.udistrital.edu.co/index.php/Tecnura/issue/view/1201

DOI: https://doi.org/10.14483/22487638.18622

INVESTIGACIÓN

Taxonomy for supply chain strategic decision

Taxonomía para caracterizar las decisiones estratégicas de la cadena de suministro

Rafael Guillermo García-Cáceres [1], Nini Johanna Rodríguez-Álvarez [2], Cesar Augusto López-Ramírez [3]

Fecha de Recepción: 28 de septiembre de 2021 **Fecha de Aceptación**: 13 de marzo de 2023

Cómo citar: García-Cáceres, R.G., Rodríguez-Álvarez, N.J. y López-Ramírez, C.A. (2022). Taxonomy for supply chain strategic decision. *Tecnura*, **27**(78), 123-141. https://doi.org/10.14483/22487638.18622

ABSTRACT

Objective: The characterization framework proposed in this work presents the strategic decisions and their characteristics and the strategic characterization structure of the supply chain.
Methodology: This article presents a framework for the strategic characterization of supply chains. The structure is supported by a group of studies that have identified and established the relationships between the decisions of the supply chain.
Results: The framework defines the various aspects of the chain that are described from the decision-making paradigm in a strategic environment. In this way, a decision-making selection process can be developed and a structure can be created to analyze the effectiveness of its management.
Conclusions: The present work resulted from the discovery of a research gap related to the lack of adequate support methodologies for making strategic decisions, providing a holistic view of the chain's competitors. An attractive future research perspective could also encompass tactical decisions alongside current strategic ones.

Keywords: Characterization, supply chains, strategic decision.

RESUMEN

Objetivo: El marco de caracterización propuesto en este trabajo presenta las decisiones estratégicas y sus características y la Estructura de Caracterización estratégica de la Cadena de Suministro.

[1]Associated Professor, Doctor of Engineering, School of Industrial Engineering, Universidad Pedagógica y Tecnológica de Colombia – UPTC. Sogamoso, Colombia.
Email: rafael.garcia01@uptc.edu.co
[2]Master of Industrial Engineering. Pontificia Universidad Javeriana. Bogotá, Colombia.
Email: rodriguez.nini@javeriana.edu.co
[3]Master of Industrial Engineering. Universidad Pedagógica y Tecnológica de Colombia – UPTC. Sogamoso, Colombia.
Email: cesar.lopez04@uptc.edu.co

Metodología: Este artículo presenta una estructura para la caracterización estratégica de cadenas de suministro. La estructura se soporta en un grupo de trabajos que han identificado y establecido las relaciones entre las decisiones de la cadena de suministro.
Resultados: La estructura define los aspectos que describen la cadena desde un paradigma de decisión, en su contexto estratégico, para desarrollar los procesos de toma de decisiones y establece las bases para analizar la efectividad de su gestión.
Conclusiones: El presente trabajo resultó del descubrimiento de una brecha de investigación relacionada con la falta de metodologías de apoyo adecuadas para la toma de decisiones estratégicas, brindando una visión holística de los competidores de la cadena. Una perspectiva de investigación futura atractiva también podría abarcar decisiones tácticas, junto con las estratégicas actuales.

Palabras clave: Caracterización, cadena de suministro, decisiones estratégicas.

1 INTRODUCTION

The evaluation of the characterization of a Supply Chain constitutes one of its basic management needs. According to (Strauss, A. and Corbin, J. (2014).), the characterization of an object corresponds to its organized description, as a probable first step in the systematization of an experience. The characterization is based on exhaustive documentation of the phenomenon in question, from its origins in the past to its current condition.
This work is supported by the systematic literature review ((Xiao, Y. and Watson, M. (2019).), whose deployment is presented below.

- Search the Literature
- Extracting Data
- Analyzing and Synthesizing Data
- Report Findings

Search The Literature

The literature on the topic shows a number of works that have tackled SC characterization, most of them focusing on tactical aspects. In some of these cases, not only is the scope of the decision level unclear, but an adequate theoretical paradigm is also lacking. Table 1 is a summary of some of these works, with an emphasis on the decision levels they address.

Table 1. Summary of SC characterization works

Source: Authors.

Reference	**Research objective**	**Decision framework characteristics and theoretical approach**	**Decision-level approach**
(García-Cáceres, R.G. and Olaya, E.S. (2006).); (García-Cáceres, R.G., Torres-V. S., Olaya-E, E.S., Díaz-G, H.B., Vallejo-D. M.R. and Castro-S., H.F. (2009).); (García-Cáceres, R.G., Núñez-Moreno, A., Ramírez-Ortiz, T. and Jaimes-Suárez, S. (2013).); (García-Cáceres, R.G., Perdomo, A., Ortiz, O., Beltrán, P. and López. K. (2014).); (López-Ramírez, C.A. and García-Cáceres R.G. (2020).)	This work develops a particular approach to network strategy characterization, both at the national and international levels. It details the functioning, synergy, and linkages between the agents of the supply and value chains.	This particular decision framework carries out a thorough analysis of basic functions, with special reference to the works of (Stone, R.B. and Wood, K.L. (2000).), (Stone, R.B., Kurfman, M.A., Rajan, J.R. and Wood K.L. (2001).). On these grounds, it covers four stages: Stage 1, which provides a general description of global agribusiness; Stage 2, which addresses SC agent roles, relevance, and contributions; Stage 3, which details management processes; and Stage 4, which provides insight into the management components of the SC.	The strategic aspects of the network are addressed

(Torres, S. and García-Cáceres, R.G. (2008).)	A reference framework is introduced, allowing the characterization of SC structures under diverse governance forms	A four-dimensional analysis model is developed in order to provide insight into different exchange modes along the SC. These correspond to "forms of interaction and coordination", "economic incentive types" and "legal contracts". The model integrates several disciplines, such as economics, strategy analysis, marketing, and organizational theory. This strategic, organizational, and governance approach is associated with the Transaction Costs Theory proposed by (Coase, R.H. (1937)) and (Williamson, O.E. (1975).), (Williamson, O.E. (1991).).	The authors approach the selection of an organizational strategy

(Simchi-Levi, D., Kaminsky, P. and Simchi-Levi, E. (2011).); (Stephens, S. (2001).)	A conceptual interpretation of the network's structure is introduced.	A four-dimensional analysis model is designed to characterize SC exchanges: Interaction and coordination forms, legal contracts, and economic incentive types. The strategic characterization focuses on the design of the spatial deployment of the network. The configuration of the model addresses: - Aggregate demand planning levels and their information sources. - Product and raw material supply source location. - Production plant location, and production methods. - Distribution channels, inventory, and product deployment. - Location and return methodologies.	Although this holistic approach covers strategic aspects, it certainly emphasizes tactical ones, especially SC functions. The characterization process is not specifically treated, except for an SC network analysis.

		The theoretical underpinning of the Supply Chain Operations Reference (SCOR) model focuses on business reference standards integrated with the supply chain paradigm.	
(Cooper, M.C., Lambert, D.M. and Pagh, J.D. (1997).), (Lambert, D.M. and Cooper, M.C. (2000).); (Lambert, D.M. and Enz, M.G. (2017).)	This work introduces a supply chain management conceptual framework, addressing both strategic and tactical elements, with an emphasis on SC network functions.	The concept of supply chain management is largely applied. In terms of network characterization, this work describes a series of methods to map the supply chain and identify those actors with whom key business activities can be carried out.	Characterization is not particularly emphasized, except for SC network treatment.

A clearly strategic approach to the SC has been developed by (García-Cáceres, R.G. and Olaya, E.S. (2006).), (García-Cáceres, R.G., Torres-V. S., Olaya-E, E.S., Díaz-G, H.B., Vallejo-D. M.R. and Castro-S., H.F. (2009).), (García-Cáceres, R.G., Núñez-Moreno, A., Ramírez-Ortiz, T. and Jaimes-Suárez, S. (2013).), (García-Cáceres, R.G., Perdomo, A., Ortiz, O., Beltrán, P. and López. K. (2014).), (López-Ramírez, C.A. and García-Cáceres R.G. (2020).), and (Martinez-Albarracín, K.D., Rivera-Roncancio, L.M. and García-Cáceres, R.G. (2019).) paying special attention to network decisions. This body of work intends to feature SCs in the context of local and international markets, especially in terms of facility network structure and agent identification, roles, and relationships. In turn, (Torres, S. and

García-Cáceres, R.G. (2008).) have addressed SC organization and governance forms about outsourcing and vertical integration. (Stephens, S. (2001).) has characterized SC processes, while (Lambert, D.M., Cooper, M.C. and Pagh, J.D. (1998).), (Lambert, D.M. and Cooper, M.C. (2000).), and (Lambert, D.M. and Enz, M.G. (2017).) have studied SC facility deployment. Therefore, the current review of the literature reveals that none of the available CS characterization studies have focused on the selection of decisions mentioned in (Riopel, D., Langevin A. and Campbell, J.F. (2005).) and (Campbell, D. and Craig, T. (2005)). In this context, this article develops a holistic conceptual framework for the characterization of strategic CS decisions.

Table 2. Strategic decisions

Source: Authors.

Decision Category	**Decision**	**Aspects considered**
Strategic Planning	Performance objectives	According to (Riopel, D., Langevin A. and Campbell, J.F. (2005).), decision-making is conditioned by factors such as organizational mission and strategies, customer expectations, the competitive environment, financial resource availability, and the logistic system, the latter comprising facilities, infrastructure, equipment, and information and communications systems.
	Vertical integration and outsourcing degrees	(Coase, R.H. (1937)) and (Williamson, O.E. (1975).), (Williamson, O.E. (1991).) explained the behavior of these parameters through the Transaction Cost Theory, which contemplates a series of conditioning factors: the specificity of key human or material assets dominating the commercial relationship; agent performance measuring difficulties among SC actors; and uncertainty in the relation between agents.

	Outsourcing	Outsourcing, onshore, nearshore, and offshore decisions have been observed to be affected by a diversity of criteria ((Kedia, B.L. and Mukherjee, D. (2009).); (Pisani, N. and Ricart, J.E. (2015).); (Lahiri, S. and Kedia, B.L. (2011).); (Slepniov, D., Brazinskas, S. and Vejrum Wæhrens, B. (2013).); (Ruivo, P., Rodrígues, J., Neto, M., Oliveira, T. and Johansson, B. (2015).); and (Panova, Y. and Hilletofth, P. (2016).). The most relevant of these criteria are intellectual property rights, political stability, economic stability, cultural affinity, geopolitical reasons, and domestic or regional demand in the area of influence of the organization. The other criteria are logistics, communications, and power infrastructure, as well as labor availability, quality, and cost.
Strategic Network level	Facilities	In terms of the logistics network, the actual outsourcing conditions depend on geographic factors at the regional, national, multinational, or global levels ((Shapiro, F. (2001).); (García-Cáceres, R.G. (2018).)). According to these authors, the decision-making criteria correspond to production costs (associated with scale economies); location costs, depending on the particular site where the facility is built; and Assignation costs, which are a function of those supply and distribution costs implied in satisfying demand and building facilities.Facility-related decision-making is usually supported by operations research (OR) and management science (MS) models.

	Communication and Information (C&I) Network	The C&I network and its associated decisions imply the existence of a shared information system all along the SC (Bayles, D.L. (2000)); (Edwards, P., Peters, M. and Sharman, G. (2011).); (Lewis, I. and Talalayevsky, A. (1997).); (Bowersox, D.J., Daugherty, P.J. (1995)); (Nickles, T., Mueller, J. and Takacs, T. (1998)); (Tilanus, B. (1997).); (Gunasekaran, A., Subramanian, N. and Papadopoulos, T. (2017).); (Pal, K. and Yasar, A.U.H. (2020).). The design of this system has to take into account a network strategy that thoroughly addresses the structure and organization of the chain. A series of significant decisions impacted the design of this network, including but not limited to information management. The degree of process centralization (such as centralized versus distributed data), adequate application loci, such as those associated with rental or purchase processes, or centralized versus distributed modes, among others; the degree of integration of an organization's diverse systems, such as those related to e-commerce and ERP (Enterprise Resource Planning), and finally, the development environment, which encompasses hardware, software, operational systems, and vendor standards.

2 Extracting Data

Methodological proposal

In approaching SC decisions and relationships at the strategic and tactical levels, (Riopel, D., Langevin A. and Campbell, J.F. (2005).) found five strategic decisions taking place in a hierarchical structure comprising two levels. In turn, (García-Cáceres, R.G. and Olaya, E.S. (2006).) have characterized SC problems and their interaction with SC decisions. These works provide a rigorous description of the

context surrounding SC characterization, the strategic aspects of which constitute the focus of the present work. Table 2 sets out the strategic decisions of the SC and the aspects considered under each of them.

The strategic decisions explained in Table 2 are related to each other by a nested hierarchy ((Riopel, D., Langevin A. and Campbell, J.F. (2005).), which, in turn, impacts tactical decisions. The top levels of this hierarchy can be seen at the top of the table, while the lower levels can be seen at the bottom. According to the literature review, the only strategic planning processes supported by a theoretical background are those based on the Economic Theory of Transaction Costs. Otherwise, the decision-selection processes found in the literature are based on SCM.

3 Analysing and Synthesizing Data

The current SC characterization framework details the strategic decisions in question, which it couples to the SC strategic characterization structure. This framework identifies the relevant features that need to be characterized and embeds them in a hierarchical decision structure. The SC strategic characterization here developed can be seen in Table 3.

4 REPORT FINDINGS - CONCLUSIONS AND RESEARCH PERSPECTIVES

The present work resulted from the discovery of a research gap related to the lack of adequate methodologies to support the selection of strategic decisions. Since it is aimed at decision-makers, some usage guidelines deserve attention: the strategic decisions themselves and their characteristics, and the actual supply chain characterization framework, which provides decision-makers with a holistic view of the competitors in the chain.

An attractive prospect of future research could also encompass tactical decisions along with current strategic ones.

Table 3. SC Strategic Characterization Structure

Source: Authors.

Deciding on the performance objectives	
Aspects	**Characterization**
Organizational mission and strategies	At this point, it is necessary to identify the strategies of the organization. It is notorious that in most cases, they are not public, along with their mission, objectives, types of products and services, and associated production and distribution coverage, among others (Campbell, D. and Craig, T. (2005)); (Fisher, M.L. (1997).). The purpose of this section is to identify and describe directional trajectories (cf. (Dermol, V. and Širca, N.T. (2018).) & Kirca, 2018) and to analyze the coherence between what CS agents express and what they develop.
Customer expectations	This stage identifies customer service performance and the assessment procedures employed by the company to evaluate it (cf. (Marand, A., Tang, O. and Li, H. (2018).), Tang, and Li 2018). The proper way to use these performance metrics must be carefully analyzed so that the service can be weighed and traced (cf. (Cyplik, P., Adamczak, M. and Hadas, L. (2013).), Adamczak, and Hadas, 2013). Among these metrics, cash, customer order, and SC cycle times certainly stand out, together with lost sales percentage, raw material average payment time, and timely delivery rate. The purpose of this assessment is not only to identify and describe the quality of performance and the level of standardization of core customer service processes. It analyzes the coherence between the organization's mission, strategies, and customer expectations.

Competitive environment	Identify and describe the competitive environment of SC in aspects such as market share percentages of rival SCs. Analyze the forms, times, places, and modes of ownership associated with their levels of innovation and value creation, among other aspects. This characterization makes it possible to establish the benchmarks necessary to understand the market and thrive in it.
Financial resource availability	The reputation and financial capacity of the SC should be determined, as they indicate its soundness and investment possibilities over time.
Logistics system	Describe the different information and communication systems and equipment in terms of technology, level of use and ownership, and overall effectiveness in supporting CS processes and management. Facilitating the creation of value and strengthening customer satisfaction competencies and capabilities.

When identifying SC transaction costs, you need to define how your agents should be organized. This involves identifying the dimensions of CS, which, according to (Coase, R.H. (1937)) and (Williamson, O.E. (1975).), (Williamson, O.E. (1991).), are: the difficulty of measuring agent performance; the inertia in the relationships between economies of scale and agents; and the specificity of the most important teams or human assets that control business relationships. It should be noted that when the values assigned to transaction cost dimensions are high, it can be said that the transaction costs themselves are also rising. As a consequence, there is a greater need to migrate towards hierarchical forms of governance.

Outsourcing decision
The outsourcing alternative (offshore, nearshore, or onshore) in which the SC is developed must be described. It is also necessary to determine if it is wise to persist with this alternative or if it is necessary to opt for another one. For this purpose, the relevant criteria that support the decision must be studied: Distance to the location of the factory; regard for intellectual property rights; affinity with the local culture; proficiency of local officers in the language used by the company to operate; logistics; communications and electrical power infrastructure; availability, quality, and cost of local labor; control of the actual operation of the organization; production costs; and timely delivery rates. In this regard, the search for greater control will privilege the near-shore option, while lower costs, especially production ones, tend to favor the offshore option. In any case, the criterion values tend to change from one country to another, so a rigorous analysis is required.
Facilities
The facility network of the SC has to be described, as well as checking if its design, implementation, and operation have made use of Decision Support Systems (DSS). The design of the logistic network depends on the selected logistic strategy: Flexibility or cost efficiency. In the former case, the decision objectives focus on optimizing production, location, and allocation costs, subject to a set of constraints that condition the flow of materials. On the contrary, if the SC seeks flexibility to expand and contract both in production and distribution, the development of contracts with third parties that facilitate operating under these conditions will be sought.

C&I **Network**
The C&I network of the SC should be described, specifically, in terms of the degree of centralization or dispersion of information; development approach, which, among others, could revolve around rent, purchase, in-house centralized, or internally distributed models; the level of integration of the corporate system, which implies paying close attention to ERP (Enterprise Resource Planning) systems and e-commerce; and (iv) Development environment, specifically as it relates to hardware, software, operating systems, and vendor standardization. In summary, this objective aims to identify the value added by the computer network in its contribution to the development of the CS.

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Tecnura

https://revistas.udistrital.edu.co/index.php/Tecnura/issue/view/1201

DOI: https://doi.org/10.14483/22487638.19522

INVESTIGACIÓN

Monitor de CO_2 para medida de la ventilación en ambientes cerrados, prevención del COVID-19 y mejora del rendimiento laboral

CO_2 monitor for measurement of ventilation in closed environments, COVID-19 prevention, and improvement of work performance

Juan Vorobioff [1] Norberto Gabriel Boggio [2]. Federico Ricardo Checozzi [3], Tamara Pinto Garrón [4], Carlos Alberto Rinaldi [5]

Fecha de Recepción: 16 de junio de 2022 **Fecha de Aceptación**: 22 de agosto de 2022

Cómo citar: Vorobioff, J., Boggio, N.G., Checozzi, F.R., Pinto-Garrón, T. y Rinaldi, C.A. (2023). Monitor de CO_2 para medida de la ventilación en ambientes cerrados, prevención del COVID-19 y mejora del rendimiento laboral. *Tecnura*, **27**(78), 142-156. https://doi.org/10.14483/22487638.19522

ABSTRACT

Objective: Humans produce and exhale CO_2, thus the concentration of this gas increases in closed environments. The CO_2 concentration of air is often used as a reference to measure the ventilation rate. The typical outdoor CO_2 concentration is approximately 400 ppm, although it can be as high as 500 ppm. Concentrations greater than 20000 ppm result in deep breathing, higher than 100000 ppm cause visual disturbances and tremors with possible loss of consciousness and over 250000 ppm may cause death. In buildings with no change on their ventilation rate, high CO_2 concentrations have negative effects on decision making and working performance. At 1000 ppm, performance is significantly reduced in six of nine decision-making metrics compared to 600 ppm. In this work, a CO_2 flexible monitor is designed to measure ventilation in closed environments.

Methodology: Electrolytic and infrared CO_2 sensors with a detection range of 350 to up to 10000 ppm were used. The used sensors have good sensitivity and selectivity to CO_2. The gas monitor has a simple calibration system, whereby software

[1]Ing. Electrónico, Doctor en Ingeniería, Mención Procesamiento de Señales e Imágenes. Profesor en FRBA Universidad Tecnológica Nacional. Investigador en Comisión Nacional de Energía Atómica. Buenos Aires, Argentina.
Email: jvorobioff@frba.utn.edu.ar
[2]Licenciado en Química, doctor en Ingeniería de Microsistemas, investigador del Instituto de Nanociencia y Nanotecnología (INN-Conicet). Profesor de la Universidad Nacional de San Martín, Buenos Aires, Argentina.
Email: norbertoboggio@cnea.gob.ar
[3]Ingeniero Electrónico. Investigador de la Comisión Nacional de Energía Atómica. San Martín, Argentina.
Email: federicochecozzi@cnea.gov.ar
[4]Bachiller en gestión y administración de las organizaciones. Estudiante de Ing. Química en FRBA Universidad Tecnológica Nacional, Argentina.
Email: tamipintog@gmail.com
[5]Lic. Química. Doctor en Química. CONICET, Instituto de Tecnologías Emergentes y Ciencias Aplicadas, Profesor en Universidad Nacional de San Martín. Comisión Nacional de Energía Atómica. Buenos Aires, Argentina.
Email: rinaldi@cnea.gov.ar

automatically adjusts the calibration curve parameters after circulating clean air. The design of a gas bench used to verify sensor calibration is also shown.
Results: A set of measurements were performed with electrochemical gas sensors and infrared (IR) gas sensors to test the functionality of the equipment. Experimental work has shown sensors have a satisfactory response for this application. The margins of error are +5% of the reading value.
Conclusions: A low cost, flexible gas monitor for indoor environments like schools, offices, laboratories, and industries was designed in this work. Due to the flexible design, a network of gas monitors strategically distributed in the different spaces of the buildings is proposed.
Fundings: Universidad Tecnológica Nacional. Comisión Nacional de Energía Atómica. Buenos Aires, Argentina

Keywords: Gas sensors, environmental monitoring, COVID-19, data processing, carbon dioxide.

RESUMEN

Objetivo: Los humanos producimos y exhalamos CO_2, por lo que la concentración de este gas aumenta en ambientes cerrados. La concentración de gas CO_2 en el aire se utiliza a menudo como referencia para medir la tasa de ventilación. La concentración típica de CO_2 al aire libre es de aproximadamente 400 ppm, aunque puede llegar a 500 ppm. Las concentraciones superiores a 20000 ppm dan como resultado una respiración profunda, superiores a 100000 ppm provocan alteraciones visuales y temblores con posible pérdida del conocimiento y superiores a 250000 ppm pueden provocar la muerte. En edificios sin cambios en su tasa de ventilación, las altas concentraciones de CO_2 tienen efectos negativos en la toma de decisiones y el rendimiento laboral. A 1000 ppm, el rendimiento se reduce significativamente en seis de las nueve métricas de toma de decisiones en comparación con 600 ppm. En este trabajo se diseña un monitor flexible de CO_2 para medir la ventilación en ambientes cerrados.
Metodología: Se utilizaron sensores de CO_2 electrolíticos y sensores infrarrojos con un rango de detección de 350 hasta 10000 ppm. Los sensores utilizados tienen buena sensibilidad y selectividad al CO_2. El monitor de gas tiene un sistema de calibración simple, mediante el cual el software ajusta automáticamente los parámetros de la curva de calibración después de hacer circular aire limpio. También se muestra el diseño de un banco de gases utilizado para verificar la calibración del sensor.
Resultados: Se realizaron un conjunto de mediciones, con sensores de gases electrolíticos químicos y sensores de gases infrarrojos (IR) probando la funcionalidad del equipo. El trabajo experimental ha demostrado que los sensores tienen una respuesta satisfactoria para esta aplicación. Los márgenes de error son 5% del valor de lectura.
Conclusiones: En este trabajo se diseñó un monitor de gas flexible y de bajo costo para ambientes interiores como escuelas, oficinas, laboratorios e industrias. Debido al diseño flexible, se propone una red de monitores de gas distribuidos estratégicamente en los distintos espacios de los edificios.
Financiamiento: Universidad Tecnológica Nacional. Comisión Nacional de Energía Atómica. Buenos Aires, Argentina.

Palabras clave: Sensores de gas, monitoreo ambiental, COVID-19, procesamiento de datos, dióxido de carbono.

1 INTRODUCTION

Current scientific studies show that there are three possible means of COVID-19 transmission: contact with contaminated surfaces, a respiratory route and possibly a fecal-oral route (Allen *et al.*, 2016). Re-

garding the respiratory route, the presence of the virus in droplets from sneezing (with a diameter of more than 5 µm) must be considered (Schibuola & Tambani, 2021). Those fall quickly to the ground, remaining in the air for a short period of time. The formation of smaller droplets (0.1 to 0.5 µm) must be considered too; these are aerosols that remain floating in indoor environments (Freire-Vinueza *et al.*, 2021). The virus can remain for hours in aerosols and a few days on surfaces. In indoor spaces, the spread of the virus by aerosols is greater than in outdoor spaces, with higher risks if ventilation is poor (Chen *et al.*, 2021). It is important to ensure proper ventilation in indoor spaces (Quesada Carvajal *et al.*, 2018). This ventilation can be natural or forced (using ventilation/air conditioning systems). Some recommendations by government/multilateral organizations specify that the minimum air renewal should be 30m^3 of clean air per hour per worker (Vorobioff *et al.*, 2020). However, for health reasons, air currents with speeds greater than 0.25 m/s are not recommended for work in non-hot environments (Li & Tang, 2021).

CO_2 concentration can be used as a good ventilation indicator (Zivelonghi & Lai, 2021). The atmospheric CO_2 level is approximately 450 ppm and this value is taken as a reference level. On the other hand, the concentration of CO_2 in exhaled air is in the order of 40000 ppm (Di Gilio *et al.*, 2021). Therefore, a measurement of 850 ppm means that 1% of the air in a room was exhaled by a person (Persily & de Jonge, 2017). The indicator P, the probability of contagion, which is a function of the time of exposure to contaminated air, is used. See Eq. (1).

$$P = 1 - e^{\left(-\int_0^T \sigma(n) f \frac{I}{n} q dt\right)} \tag{1}$$

where T is the exposure time, n is the number of people in a space, I is the number of people infected, $\sigma\,(n)$ is 1 if $n > 0$, otherwise 0, q is a unit of infection or a value determined as a function of activity and specific people (Satish *et al.*, 2012). The variable f (see Eq. 2) is the fraction of air rebreathed, estimated based on the measured CO_2 concentration C, the exhaled concentration C_a and the concentration in open environments C_0 (García Alvarado *et al.*, 2016).

$$f = \frac{C - C_0}{C_a} \tag{2}$$

Many organizations recommend a maximum threshold of 800 ppm (Tusman *et al.*, 2020). The UK Health and Safety Executive Agency in its guidance for air conditioning and ventilation during the Coronavirus pandemic recommends that CO_2 measurements should be used as an indicator to in-

door ventilation rather than treating them as safe limits (Ostro *et al.*, 2000). Outdoor levels around 400 ppm and indoor levels with a consistent CO_2 value of less than 800 ppm are likely to indicate that a space is properly ventilated (Gil-Baez *et al.*, 2021). In a similar way, the Argentine Ministry of Health says that "One strategy to indirectly assess the degree of indoor air tightness is CO_2 (carbon dioxide) monitoring. It is recommended to increase how opened are doors and windows when the level of CO_2 exceeds 700 ppm (parts per million of air mass)" (Sanchez Quintero *et al.*, 2021).

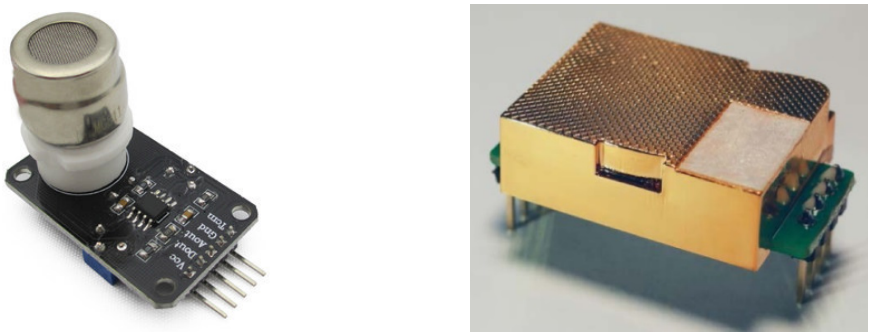
In buildings with no change on their ventilation rate, high CO_2 concentrations have negative effects on decision making and working performance. At 1000 ppm, performance is significantly reduced in six of nine decision-making metrics compared to 600 ppm. At 2500 ppm CO_2, performance is reduced in seven of nine performance metrics (Satish *et al.*, 2012).

2 METHODOLOGY

A small, portable, low cost and flexible gas monitor was designed and built. Electrochemical gas sensors model MG811 and infrared (IR) gas sensors model MH-Z19C (manufactured by Winsen) were used (see Fig.1).

The MG811 sensor works through an electrochemical reaction that occurs when carbon dioxide passes over the sensor (Shen, 2014). The output voltage is measured to estimate CO_2 concentration, with 350ppm to 10000ppm detection ranges. The used sensors show good sensitivity and selectivity to CO_2, low dependence to temperature and humidity, good stability and repeatability, and low cost (Rodríguez *et al.*, 2019).

The IR gas sensor is a general use sensor that utilizes NDIR (non-dispersive infrared) principles to detect CO_2 concentration in the air. It has good selectivity, temperature compensation and a long useful life (Massacane *et al.*, 2010). Measurements can be made via serial, analogical or PWM output; all of them work simultaneously. It combines a reliable IR absorption gas detection technology with low cost and a reduced size.



(a) Sensor MG811 **(b)** MH-Z19C

Fig. 1. Gas monitor

***Source**: Authors*

The gas monitor uses the previously mentioned sensors, and it can use up to eight sensors. It also has a simple calibration system which can set a reference level by means of a micro-pump that circulates clean ambient or synthetic air (Acosta Pérez *et al.*, 2016), as shown in Fig. 2. The calibration curve parameters are adjusted automatically by software, to indicate the concentration levels in ppm (Díaz, 2021). Exhaled breath measurements were made on indoor conditions. It was also measured with a gas bench for sensor calibration that can mix CO_2 and synthetic air in controlled flow and concentration conditions is available too.

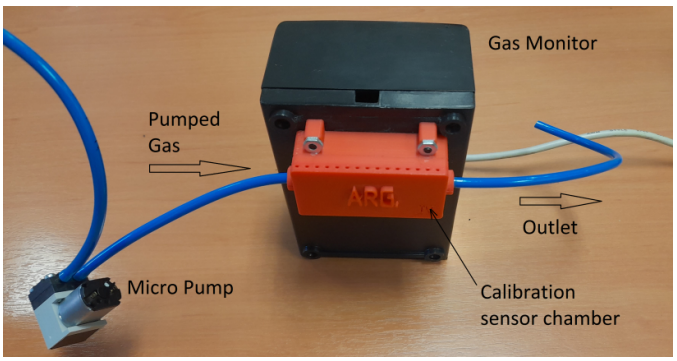


Fig. 2. Gas monitor with calibration sensor chamber

***Source**: Authors*

CO_2 monitor results are indicated on LCD display and via computer software. Optionally, wireless transmission can be added to display the results on cellphones.

MG811 sensor calibration

The measured concentration can be calculated using Eq. 3:

$$c = d^{(a-v)/b} \tag{3}$$

Where:

c – CO_2 concentration in ppm

d – Constant equal to 400

v – Sensor voltage measurement in mV

a – A parameter adjusted during calibration with an initial value of 1500

b – Constant equal to 600

To calibrate the chemical sensor, a is calculated using Eq. 4:

$$a = v + b\frac{ln(c_1)}{\ln(d)} \tag{4}$$

Where c_1 is the real concentration value. For example, for a well ventilated room it would be 400ppm. In practice, it is assumed that $d = c_1$ and in this case the adjustment equation will be:

$$a = v + b \tag{5}$$

If a decision is made to change c_1 then b and d should be changed using Eq. 6 and 7:

$$d = c_1 \tag{6}$$

$$b = 100lnc_1 \tag{7}$$

Once sensors are calibrated, the chamber is removed.

Gas bench

A gas bench was used to calibrate the sensors. This control system can mix different gases with precision; those gases flow through the sensor chamber described on the previous section. The system is controlled by a computer connected to a hardware controller. This hardware includes gas lines, four mass flow controllers (MFC), electrovalves, humidifiers and a command module responsible for the gas mix with controlled caudal, humidity and concentration. Synthetic air (99.999%) and CO_2 (2000ppm) tubes provided by Indura Argentina S.A fed the bench.

Gas lines can provide a gas mix with controlled humidity at the desired concentration range. The mix procedure is accomplished with high precision thanks to the use of MFCs. Once the desired mix is obtained, it's injected into a measurement chamber where sensors are located. The gas line has 4 input lines connected to high pressure tubes (see Fig. 3). Lines 1 and 2 are both connected to the synthetic air tube while lines 3 and 4 are connected to target gases/pollutants (in this case CO_2). MFCs allow the flow of gas from a specific line through a voltage signal.

MFC connected to the second allows a 100cm^3/min maximum flow and the MFCs connected to the other lines allow a 500cm^3/min maximum flow.

The gas bench guarantees the purity of gas mixes injected into the chamber, controlling the flow and concentration of any external pollutant/gas connected to one of the lines.

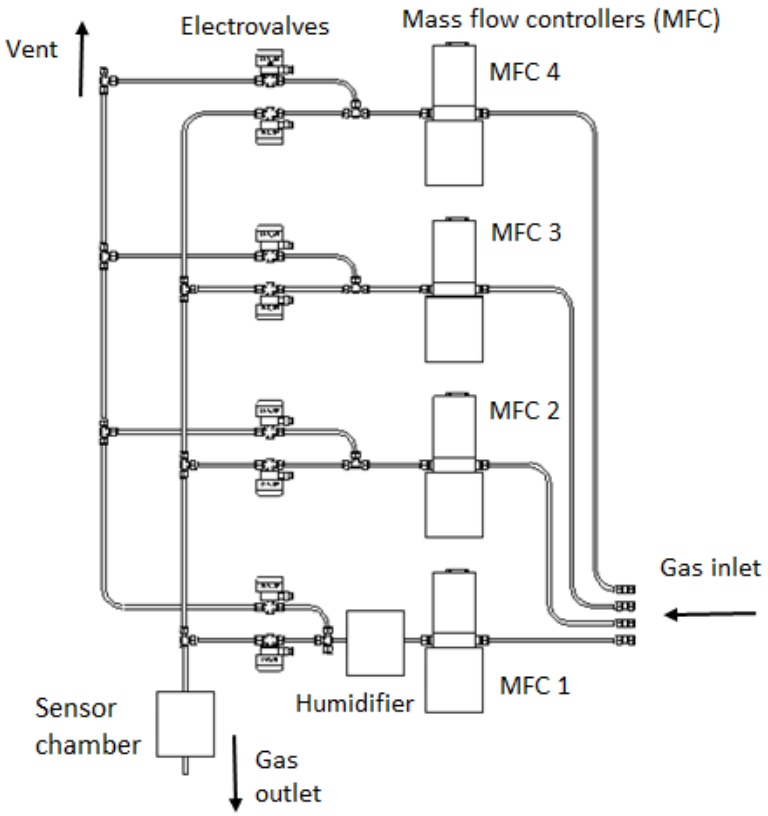


Fig. 3. Simplified gas line scheme.

***Source**: own preparation*

Four MFCs (MKS instruments, model 1179A01352CS1BV) are used to control the flow of the lines

with a 500/100cm^3/min maximum range. Those MFCs adjust and measure the desired flow. An MFC command module model SDPROC Version 1.03, manufactured by Aalborg, is used to control and read the MFCs. This controller connects to the computer to send data and execute commands via an RS-232 to USB converter.

Software was developed to communicate with MFCs, register flows for each line, and control the closure and aperture of electrovalves. The implemented algorithms calculate the value of those flows. Gas mix procedures can be automatized by setting concentration sequences. These sequences are composed of different mixes at different time intervals. Flow levels are plotted in real time. Gas sensors levels can be read at the gas monitor software interface and optionally through the gas bench software. Fig. 4 shows the bench's graphical interface. The total flow, desired output concentrations, incoming flow levels, interval times and repetitions per sequence can be set.

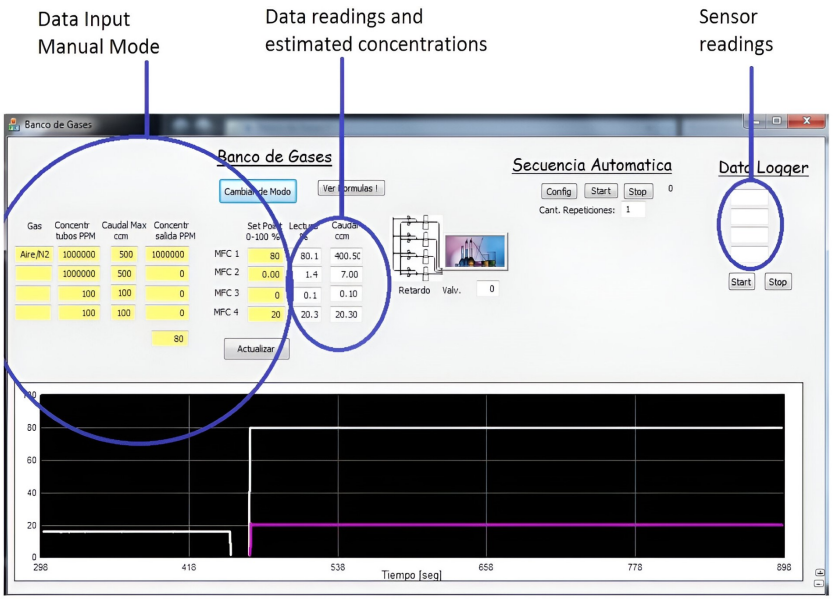


Fig. 4. Gas bench graphic interface

Source: *Authors*

Because the gas tubes have a specific gas concentration, the desired concentration of a gas to measure is achieved by diluting specific gases in a carrier gas (e.g., nitrogen, pure air, etc.). The proportion (for each gas to measure) of the configured total flow to the gas chamber is chosen in such a way that the diluted concentration is the desired one. This is done indirectly through MFC set points (percentage

of the max flow of a tube), as seen in Eq. 8. The flow of carrier gas (therefore its set point, $SP(1)$) is constrained by the other flows and the configured total flow, as seen in Eq. 9.

$$SP\left(i\right)=\frac{C\left(i\right)100}{CM\left(i\right)}=\frac{p\left(i\right)\cdot CT\cdot 100}{CM\left(i\right)}=$$

$$=\frac{concentr_{out(i)}\cdot CT\cdot 100}{concentr_{tube(i)}\cdot CM\left(i\right)};i=2,3,4 \tag{8}$$

$$SP\left(1\right)=\frac{C\left(1\right)100}{CM\left(1\right)}=\frac{100}{CM\left(1\right)}\cdot\left[CT-\sum_{i=2}^{4}C\left(i\right)\right]=$$

$$=\frac{100}{CM\left(1\right)}\cdot\left[CT-\sum_{i=2}^{4}\frac{SP\left(i\right)}{100}CM\left(i\right)\right] \tag{9}$$

Where:

$i=2,3,4\ (gases\ to\ measure)\ ;i=1\ (carrier\ gas)$

CT: configured total flow

$concentr_{out}\left(i\right)$: desired output concentration for line i

$concentr_{tubo}\left(i\right)$: configured tube concentration i

$C\left(i\right)$: Flow for MFC i

$p\left(i\right)$: Proportion of total flow for MFC i

$CM\left(i\right)$: Max flow for MFC i (100 cm^3/min if i=3,4 or 500 cm^3/min if i=1,2)

$SP\left(i\right)$: set point sent to MFC i, expressed in percentage

In this work, only two MFCs are used, one for CO_2 and one for the carrier (pure air).

Gas chamber

The sensors were mounted in chambers made of plastic bottles, with inlet tubes to connect to the gas bench and outlet to the environment. Those tubes were sealed to avoid leakages (see Fig. 5). Small bottles were chosen to avoid the need for an excessive gas volume to fill the chamber.

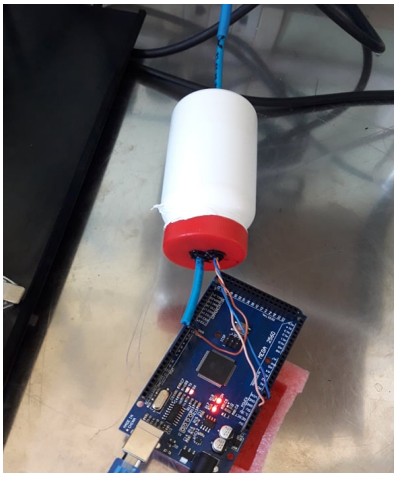


Fig. 5. Gas chamber

***Source**: Authors*

Measurement procedures

MH-Z19C sensor measurements were made injecting a mix of synthetic air and CO_2 as it is shown in Table 1. The first step was a purge with conditions similar to well ventilated environments (400ppm). Later steps increment the concentration level up to the sensor's limit detection range.

Table 1. Gas mixture concentrations

Source: own preparation

Desired CO_2 concentration [ppm]	**Set Point 1 Synthetic air [%]**	**Set Point 4 CO_2 (2000ppm) [%]**	**Time [minutes]**
400	16	20	11
800	12	40	11
1200	8	60	11
2000	0	100	11

MG811 sensor measurements were made on an indoor environment, by exposing it to exhaled breath to observe the transient response of the sensor. The room where the measurements were made was properly ventilated and vacant (except for the person responsible for the measurement itself), and

the sensor was blown repeatedly with 3 minutes pauses between every attempt, to be able to observe transient effects.

MHZ19C response can be seen in Fig. 6. Sensor response can be divided in three stages: an initial stage where air flows into the chamber replacing old air with a different concentration, a transient stage where the sensor reacts to the new concentration and a stationary stage where the current concentration level can be measured.

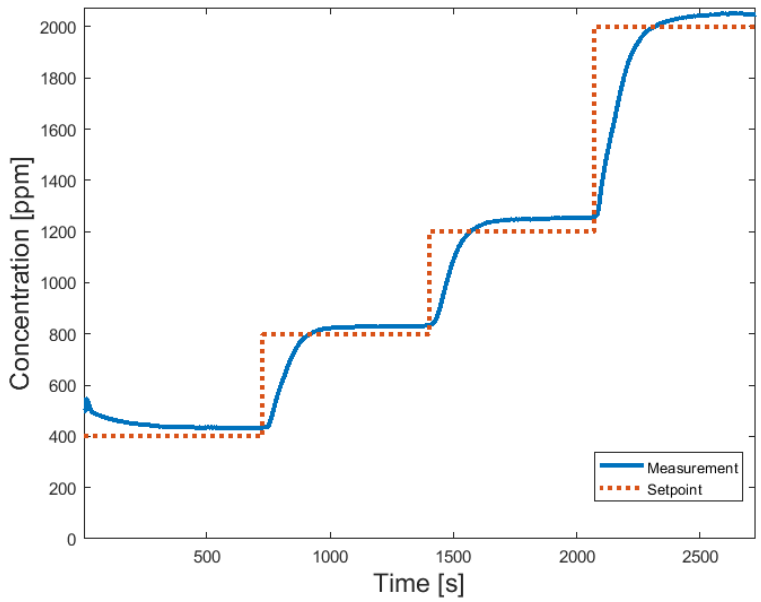


Fig. 6. MHZ19C response to different CO_2 concentrations.

***Source**: Authors*

The measured concentrations and setting time can be seen in Table 2. Observed values are within the error margins given by the sensor accuracy ($\pm 50ppm + 5\%$ reading value) and MFC accuracy (1% max range).

MG811 response can be seen in Fig. 7. As expected, the signal is stronger after exposure to exhaled breath because of the increased CO_2 levels, yet there are transient effects because of sensor saturation. Those effects can last a few minutes to wear off. The procedure is repeated 5 times obtaining adequate results.

Table 2. Setpoint, setting time and measured concentration

Source: own preparation

Set point [ppm]	Concentration [ppm]	Setting time [s]
400	430	455
800	830	253
1200	1255	409
2000	2052	552

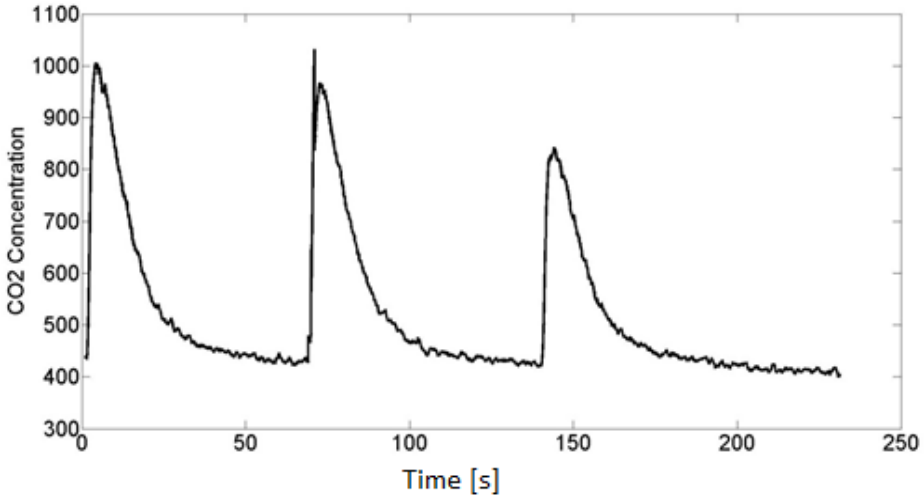


Fig. 7. MG811 response to multiple exhalations.

***Source**: Authors*

3 CONCLUSIONS

CO2 level is a good indicator of COVID-19 contagion risk on indoor environments. It is also important to analyze gas levels to avoid diminished labor performance. A low cost, flexible gas monitor for indoor environments like schools, offices, laboratories and industries was designed in this work. Gas sensors were calibrated using a gas bench, to improve measurement reliability. Gas monitors have an alarm that warns the need to ventilate the environment. Experimental work demonstrated that sensors have a satisfactory response for this application. As future work, it remains to study possible

interfering substances that cause an increase in the signal produced by CO2 as false positives or in the event that the interferents displace CO2, as false negatives, in order to modify the correlation between the level of CO2 and the possible presence of COVID. Different models of sensors should be tested and their sensitivity and specificity compared to different gases should be compared.

FUNDINGS

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https://revistas.udistrital.edu.co/index.php/Tecnura/issue/view/1201

DOI: https://doi.org/10.14483/22487638.19916

INVESTIGACIÓN

Análisis energético de edificios, mediante termografía infrarroja aplicada con un dron cuadricóptero Parrot Anafi thermal

Energy analysis of buildings using infrared thermography applied with a Parrot Anafi thermal quadricopter drone

Didier Aldana-Rodríguez [1], Cristian Lozano-Tafur [2]

Fecha de Recepción: 8 de septiembre de 2022 **Fecha de Aceptación**: 17 de octubre de 2022

Cómo citar: Aldana-Rodríguez, D. y Lozano-Tafur, C. (2023). Análisis energético de edificios, mediante termografía infrarroja aplicada con un dron cuadricóptero Parrot Anafi thermal. *Tecnura*, **27**(78), 157-171. https://doi.org/10.14483/22487638.19916

Abstract

Objective: The general objective of this study is to validate the efficiency of building energy analysis through the technique of passive infrared thermography, both qualitative and quantitative, which allows for the optimization of resources through the early detection of leaks in windows, ventilation systems, and/or air conditioning, as well as possible damage in solar panels installed on building roofs.

Methodology: To implement the diagnostic procedure, a handheld Flir E5 thermal camera and the Parrot Anafi Thermal quadcopter drone equipped with a Flir Lepton thermal camera were used. These devices allowed for the acquisition of graphs called thermograms, in which temperature gradients are observed. These were analyzed using the Flir Tools software to search for possible anomalies. This methodology was developed based on the procedures established in the standards (ASTM E1862-97 (2010)), (ASTM E1933–99a (2017)), and (ISO 18434-1 (2008)), among others, which define standardized procedures for the application of infrared thermography as a non-destructive inspection method.

Results: Three thermograms were obtained from two buildings of the Fundación Universitaria Los Libertadores, Bogotá campus (Bolívar building and Santander building), two thermograms of the exterior facade and one of the roof. The analysis of these thermograms with qualitative and quantitative thermography allowed for the detection of energy losses and anomalies in the exterior windows and roof, such as leaks and/or heat or cold entries, in the ventilation ducts, and on the exterior facades. The deltas and/or temperature gradients of around 3°C measured at the windows made it possible to detect temperature leaks in the frames and/or joints of the windows, likewise, temperature gradients between 5°C – 11°C allowed for the detection of leaks in the ventilation ducts.

[1]Estudiante de Doctorado en informática Magíster en Ingeniería Mecánica, Ingeniero Aeronáutico e Ingeniero Electrónico. Docente de tiempo completo de la Fundación Universitaria los Libertadores y Docente Hora catedra de la Escuela de Aviación del Ejército. Bogotá, Colombia.
Email: didieraldanarodriguez@cedoc.edu.co

[2]Estudiante de Doctorado en informática, Magister en materiales y procesos e Ingeniero Aeronáutico. Docente de tiempo completo la Fundación Universitaria los Libertadores. Bogotá, Colombia.
Email: rclozanot@libertadores.edu.co

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DOI: https://doi.org/10.14483/22487638.19916

Conclusions: Qualitative and quantitative passive thermography allows for the effective energy evaluation and maintenance of buildings through the inspection of facades, building roofs, and ventilation and refrigeration equipment. For this, it is important to correctly configure in the camera and/or in the thermogram post-processing software, the values of thermal emissivity of the materials under inspection and the apparent reflected temperature, which are the two most relevant and influential parameters in the results when using the infrared thermography technique, because the values of the deltas and temperature gradients are dependent on these two parameters.
Financing: This research output is associated with the research project titled: "Energy and Structural Analysis of Buildings, through Infrared Thermography and Artificial Intelligence Algorithms" associated with the Fundación Universitaria Los Libertadores. It is also associated with the electronics and drones seedbed of the Escuela de Aviación del Ejercito de Colombia (ESAVE).

Keywords: Drones, infrared thermography, building inspection, energy assessment.

Resumen

Objetivo: El objetivo general de este estudio es validar la eficiencia la evaluación energética de edificios mediante la técnica de termografía infrarroja pasiva, cualitativa y cuantitativa que permita la optimización de recursos mediante la detección temprana de fugas en ventanas, sistema de ventilación y/o aire acondicionado, así como posibles daños en paneles solares instalados en techos de edificios.
Metodología: Para implementar el procedimiento de diagnóstico, se utilizó una cámara termográfica de mano Flir E5 y el dron cuadricóptero Parrot Anafi Thermal que está equipado con una cámara termográfica Flir Lepton, equipos que permitieron obtener gráficas llamadas termogramas en los que se observan gradientes de temperatura, los cuales se analizaron mediante el Software FlirTools en busca de posibles anomalías. Esta metodología fue desarrollada con base en los procedimientos establecidos en las normas (ASTM E1862-97 (2010)), (ASTM E1933–99a (2017)) e (ISO 18434-1 (2008)) entre otras, en las que se definen procedimientos estandarizados para la aplicación de termografía infrarroja como método de inspección no destructivo.
Resultados: Fueron obtenidos tres termogramas de dos edificios de la Fundación Universitaria Los Libertadores sede Bogotá (edificio Bolívar y edificio Santander), dos termogramas de la fachada exterior y uno del techo. El análisis de estos termogramas con termografía cualitativa y cuantitativa permitió detectar pérdidas de energía y anomalías, en las ventanas exteriores y el techo, tales como fugas y/o entradas de calor o frío, en los ductos de ventilación y en las fachadas exteriores. Los deltas y/o gradientes de temperatura de alrededor de 3°C medidos en las ventanas, permitieron detectar fugas de temperatura en los marcos y/o uniones de las ventanas, así mismo gradientes de temperatura entre los 5 °C – 11 °C permitieron detectar fugas en los ductos de ventilación.
Conclusiones: La termografía pasiva cualitativa y cuantitativa permite la evaluación energética y mantenimiento eficaz de edificios, mediante la inspección de fachadas, techos de edificios, equipos de ventilación y refrigeración. Para ello es importante configurar correctamente en la cámara y/o en software de postprocesamiento de termogramas, los valores de emisividad térmica de los materiales bajo inspección y la temperatura aparente reflejada, que son los dos parámetros más relevantes e influyentes en los resultados al momento de utilizar la técnica de termografía infrarroja, porque los valores de los deltas y gradientes de temperatura están en función de estos dos parámetros.
Financiamiento: Este producto de investigación está asociado al proyecto de investigación titulado: "Análisis energético y estructural de edificios, mediante termografía infrarroja y algoritmos de inteligencia artificial" asociado a la Fundación Universitaria Los Libertadores. También está asociado al semillero de electrónica y drones de la Escuela de Aviación del Ejercito de Colombia (ESAVE)

Palabras clave: Drones, termografía infrarroja, inspección de edificios, evaluación energética.

1. INTRODUCCIÓN

Las pérdidas energéticas en edificios producen disminución del confort térmico de las personas que permanecen dentro de estas estructuras, estas pérdidas derivan en gastos adicionales por fugas en tuberías o ductos de ventilación o refrigeración, por procesos de transferencia de calor anormales en ventanas o daños en aislantes térmicos, también sobrecargan los sistemas de aire acondicionado en climas cálidos y promueven el uso innecesario de sistemas eléctricos de calefacción en climas más fríos, generando consumos eléctricos elevados (Lucchi, E. (2018)).

Actualmente para cuantificar esas pérdidas se llevan a cabo análisis higrotérmicos (Hamdaoui, M.-A., Benzaama, M.-H., El Mendili, Y., & Chateigner, D. (2021)) para analizar la humedad y temperatura de un entorno, así como análisis de envolventes térmicas para determinar los gradientes o diferencias de temperatura adecuadas entre el exterior e interior de un edificio, con el fin de asegurar la eficiencia térmica, estos estudios generalmente se llevan a cabo con higrómetros para medir la humedad, anemómetros para medir las corrientes de aire, termómetros, termocuplas y pirómetros para medir la temperatura (Rathore, P. K. S., Gupta, N. K., Yadav, D., Shukla, S. K., & Kaul, S. (2022)).

Existe una técnica como alternativa eficiente para la auditoria energética de edificios, llamada termografía infrarroja por sus siglas en inglés IRT (InfraRed Thermography), que se basa en el principio físico que todo cuerpo que tenga una temperatura superior a la temperatura del cero absoluto (-273°C) emite energía térmica en forma de radiación infrarroja, que es un tipo de radiación electromagnética no visible al ojo humano y proporcional a la emisividad del material, la cual es una propiedad intrínseca de los materiales que establece que tanta radiación infrarroja emite un cuerpo y se cuantifica en un valor adimensional en un rango entre 0 y 1. La IRT permite medir la radiación infrarroja emitida por los cuerpos, mediante una cámara termográfica que tiene un sensor microbolométrico que convierte la radiación medida en señales eléctricas digitales, que mediante algoritmos de tratamientos de señales permiten crear una imagen de gradientes térmicos llamada termograma como se muestra en la figura **1**, el cual permite observar los distintos gradientes de temperatura presentes en la superficie del objeto, proporcionales a la radiación infrarroja que este emite. En un termograma las temperaturas más altas se representan con los colores más brillantes y las temperaturas más bajas con

colores más opacos, como se observa en el rango mostrado a la derecha de la figura **1**. Las imágenes obtenidas por estas cámaras pueden almacenarse o transmitirse en tiempo real (Qu, Z., Jiang, P., & Zhang, W. (2020)).

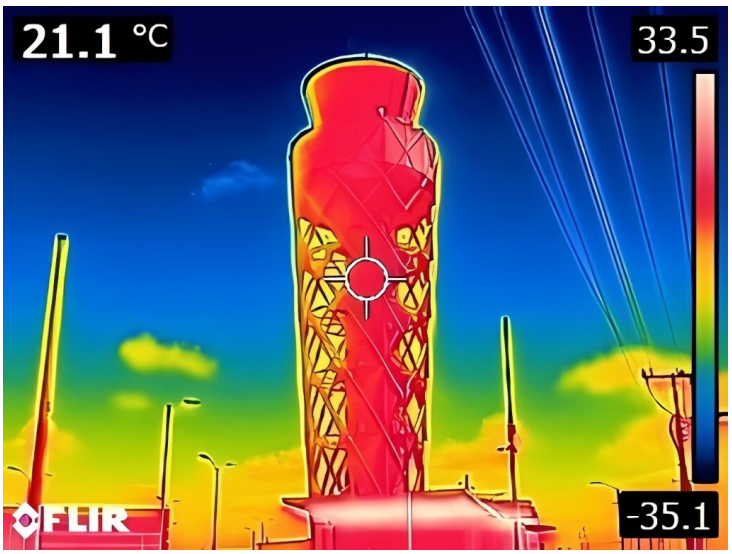


Figura 1. Termograma torre de control Aeropuerto el Dorado Bogotá

Fuente: Autores.

Hay dos tipos de IRT la pasiva y la activa, la primera no requiere que el material sea estimulado para generar una respuesta, debido a que por la misma operación de los componentes o del ambiente estos se calientan y emiten radiación infrarroja que puede ser detectada; La segunda es la IRT activa la cual requiere que el elemento bajo inspección sea estimulado por una fuente externa como lámparas halógenas, pulsos de corriente y otros, con el fin de forzar una respuesta en el componente para que emita una mayor radiación infrarroja. Cada uno de esos tipos a su vez se subdividen en termografía cualitativa y cuantitativa, en la primera se extraen datos numéricos de los termogramas, mientras que en la segunda se analizan las imágenes de manera descriptiva para comparar patrones y/o gradientes térmicos entre imágenes (Tran, Q. H. (2021)).

La IRT es una herramienta útil para la inspección de estructuras y componentes, la técnica se fundamenta en el hecho que cuando la temperatura de un equipo o estructura incrementa, puede ser un indicio que algo anormal está sucediendo, esta temperatura está relacionada con un aumento de energía térmica y de radiación infrarroja, la detección y cuantificación de esta radiación infrarroja

permite evaluar problemas existentes rápido y sin contacto. Es una técnica ampliamente utilizada como método de inspección no destructiva por sus siglas en inglés NDT (Non Destructive Test), porque permite analizar gran variedad de procesos. Actualmente la termografía es utilizada para el monitoreo de condición en varias ramas de la industria incluyendo la inspección de edificios (Garrido, I., Lagüela, S., Otero, R., & Arias, P. (2020)). El análisis de termogramas mediante el software especializado Flir Tools que se muestra en la figura **2**, permite evaluar los sitios más comunes en los que se generan pérdidas térmicas como son las ventanas exteriores y puertas de acceso a techos, para buscar fugas y/o entradas de calor o frío en los tejados y muros exteriores, humedad por roturas tubería o filtración de agua, también fallos eléctricos de componentes de aire acondicionado.

Figura 2. Análisis de un termograma con FLIR Tools

Fuente: Autores.

En los últimos 10 años el uso de drones por sus siglas en inglés RPAS (Remote Piloted Aircraft System), ha agregado valor a la IRT , embarcando cámaras termográficas en estos vehículos. Se denomina sistema porque se compone de tres subsistemas: $i)$ la aeronave no tripulada, $ii)$ la estación de control en tierra y $iii)$ el enlace de comunicaciones entre aeronave y estación terrena, subsistemas que se articulan entre sí de manera sinérgica, para obtener un vuelo autónomo, controlado y estable de la aeronave. Los RPAS se clasifican en dos tipos según su forma de despegue y aterrizaje, el primer tipo son los de despegue horizontal los cuales se caracterizan por ser de ala fija, recorrer grandes distancias y alcanzar grandes velocidades. El segundo tipo los de despegue vertical que se caracterizan por tener una o varias alas giratorias, poseen la capacidad de realizar vuelo estático sostenido y estable; situación que resulta ventajosa al momento de inspeccionar edificios porque tienen buena

maniobrabilidad y controlabilidad (Daffara, C., Muradore, R., Piccinelli, N., Gaburro, N., de Rubeis, T., & Ambrosini, D. (2020)). Se subdividen en helicópteros y multirrotores, siendo estos últimos los usados para inspección de edificios. Se denominan tricóptero si tienen 3 motores, cuadricóptero si tienen 4 motores, hexacóptero si tienen 6 motores y octocópteros si tiene 8 motores. Un ejemplo de un cuadricóptero es el Parrot Anafi Thermal que se muestra en la figura 3, dron que está equipado con una cámara termográfica marca Flir referencia Lepton con resolución térmica de 120 x 90, un rango de temperaturas de entre -15 y 400°C grados Celsius y una resolución para las mediciones de 0,01 grados. Por otro lado la cámara de mano Flir E5 que también se muestra en la figura 3 tiene un rango de temperatura de entre -20 y 250 °C una resolución térmica de 120 x 90 y un resolución de medición de 0,1 °C

Figura 3. Equipos utilizados para toma de termogramas

Fuente: Autores.

El objetivo general de este estudio es validar la eficiencia del análisis energético de edificios mediante la técnica de IRT, aplicada con una cámara de mano Flir E5 y un dron Parrot Anafi Thermal. El desarrollo metodológico inició con una búsqueda de literatura relacionada en SCOPUS, posteriormente se desarrolló la inspección de las fachadas y techos de dos edificios de la Fundación Universitaria Los Libertadores ubicada en la localidad de Barrios unidos de la ciudad de Bogotá, obteniendo 3 termogramas analizados con el software Flir tools, con el fin de encontrar pérdidas de energía o fallos

de componentes.

2. MATERIALES Y MÉTODOS

El tipo de investigación es cuantitativa de tipo descriptivo porque fue realizado un análisis de datos con el propósito de encontrar factores y características del objeto de estudio, que en este caso es el techo y la fachada exterior del sexto piso del edificio la sede Bolívar y el techo del edificio de la sede Caldas de la Fundación Universitaria los Libertadores en la Ciudad de Bogotá. Como primer paso metodológico fue realizada una búsqueda sistemática de literatura científica en la base de datos SCOPUS usando diferentes combinaciones de 5 palabras claves en inglés, Thermography, Buildings, Inspection, Energy Assessment and drone, búsqueda que arrojó un total de 97 referencias distribuidos en 50 artículos de conferencia, 29 artículos de resultados, 8 artículos de revisión y 8 en otros tipos. Posteriormente el estudio fue complementado con otras 15 fuentes extraídas de Google Académico, conformando las 112 fuentes que fueron analizadas y filtradas usando la metodología para revisión sistemática de literatura descrita en (Perez Rave., J.I. (2013)) para seleccionar las 14 referencias utilizadas en el artículo.

Las 97 referencias de SCOPUS se exportaron al programa Vosviewer que es una herramienta de software para construir y visualizar redes bibliométricas como se muestra en la figura **4**, con el propósito de encontrar correlación de los estudios y las palabras clave, las cuales permitieron analizar y delimitar de una manera precisa el análisis energético en edificios mediante IRT. En esta misma figura se observa la correlación mostrada por Vosviwer entre los estudios encontrados mediante las palabras clave, el diámetro de los nodos indica la densidad y la frecuencia con la que aparece la palabra clave permitiendo seleccionar las más relevantes y que se correlacionan directamente con el estudio; en este caso las más relacionadas y que son más transversales a las 97 fuentes son termografía, evaluación energética, edificios, utilización de la energía, conservación de la energía, radiación infrarroja, drones y utilización de la energía. Al seleccionar el nodo de drones, se filtran las palabras claves de los estudios relacionados con ese tema específico , allí cada color representa una subárea del estudio, el uso de drones para aplicar termografía en edificios está marcado en color verde, el color amarillo está relacionado con la energía térmica y aprovechamiento de energía solar en edificios, la roja la eficiencia energética como se mide con la técnica de termografía y la morada con defectología y

medición de pérdidas de calor. Así mismo la gráfica permite ver la correlación de análisis energético y los procesos físicos y parámetros asociados, así como las posibles causas y parámetros que influyen y permiten caracterizar las pérdidas de energía. Estas fuentes llevaron al desarrollo metodológico del proyecto.

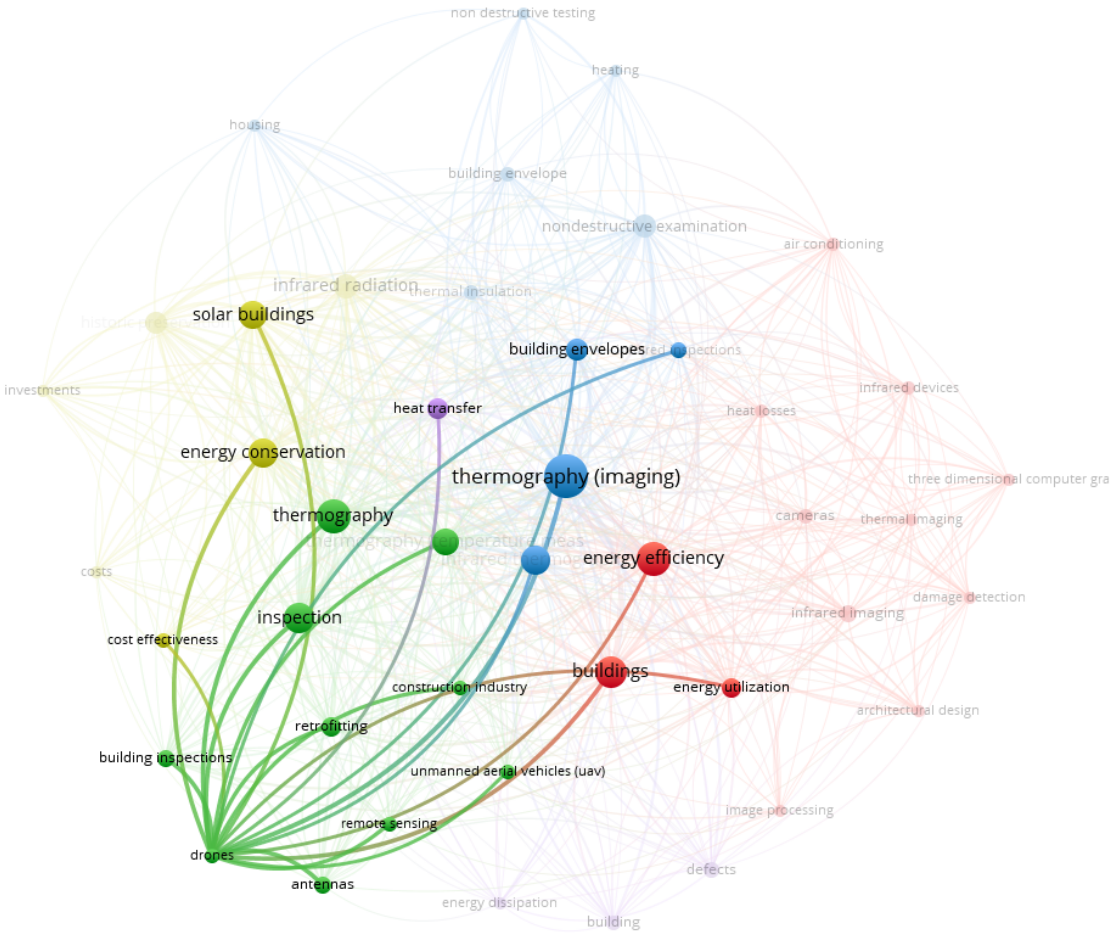


Figura 4. Estudios relacionados con drones, termografía e inspección energética.

Fuente: Autores.

En la investigación de las normas internacionales asociadas a la IRT se determinó que no hay una norma específica para la aplicación de termografía en edificios, pero hay normas estandarizadas para la aplicación de esta técnica en la industria y otros usos, normas que tienen aspectos y parámetros transversales que se pueden utilizar para la aplicación de termografía en análisis energético de edificios,

las normas más relevantes son (ISO 18434-1 (2008)) *Monitoreo y diagnóstico de máquinas con termografía procedimientos generales*, (ASTM E1933–99a (2017)) *Práctica estándar para medir y compensar emisividad usando cámaras termográficas*, (ASTM E1862-97 (2010)) *Práctica estándar para medir y compensar temperatura reflejada con cámaras termográficas*, (ISO 52000-1:2017 (2017)) *Evaluación global de la eficiencia energética de los edificios* y la norma española norma UNE (EN 13187:1998 (1998)) *Prestaciones térmicas de las que debe disfrutar un edificio*. Bajo los procedimientos establecidos en estas normas fueron obtenidos los 3 termogramas que permitieron determinar algunos aspectos energéticos de los edificios inspeccionados. En la fase de toma de los termogramas de los edificios, la técnica utilizada fue la IRT pasiva de tipo cualitativo complementada con datos cuantitativos. Los pasos metodológicos fueron los siguientes:

- Paso 1: configurar y calibrar el dron y la cámara térmica de este, siguiendo los pasos del manual del Parrot Anafi Thermal (Parrot (n.d.)).
- Paso 2: configurar la Cámara Flir E5 siguiendo los pasos del Manual.
- Paso 3: determinar la temperatura aparente reflejada por los objetos y/o alrededor del edificio, que puede reflejar radiación en el edificio bajo estudio y afectar la medida al agregar temperatura que no es emitida por este; este procedimiento se realizó bajo la norma (ASTM E1862-97 (2010)).
- Paso 4: fue necesario determinar el valor de la emisividad térmica del objeto a medir siguiendo los procedimientos establecidos en la norma (ASTM E1933–99a (2017)), con el fin de lograr obtener una medida confiable y exacta de temperatura. La emisividad es un valor numérico adimensional que esta entre 0 y 1 dependiendo del material, entre más se acerque a 1 más radiación térmica emite un cuerpo y por ende es más confiable la lectura.
- Paso 5: tomar los termogramas siguiendo los procedimientos establecidos en la norma (ISO 18434-1 (2008)) (ISO.International Standar Organizatión., s. f.).
- Paso 6: analizar los termogramas usando el programa FlirTools.
- Paso 7: Comparar los resultados del análisis del paso 6 con los criterios de aceptación descritos en la norma (ISO 52000-1:2017 (2017)), (ISO 52000-1:2017 (2017)), y la norma UNE (EN

13187:1998 (1998)) que establece todas las prestaciones térmicas de las que debe disfrutar un edificio.

3. RESULTADOS

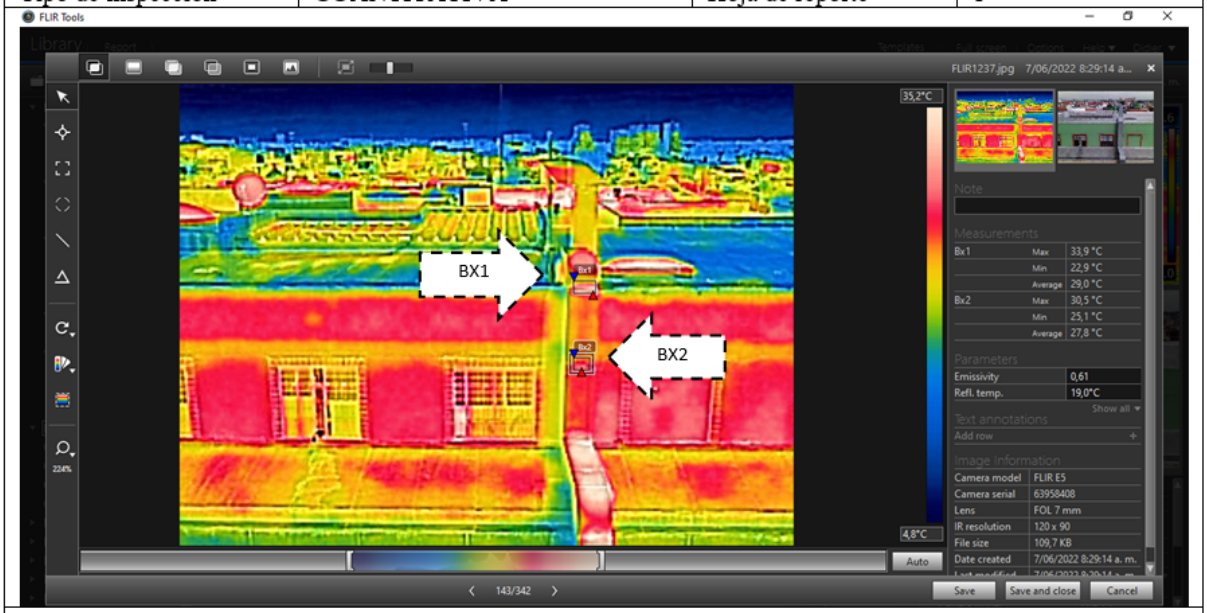
Como resultado del paso 1 y 2 se configuró en la cámara una distancia horizontal de medición de 10 mts desde la cámara al edificio para el termograma 1, una distancia horizontal de 15 mts desde la cámara al edificio para el termograma 2, y 5 metros verticales desde la cámara térmica del dron al panel solar del techo para el termograma 3. Fueron elegidas las paletas de colores lava y arcoíris que permitieron mejor contraste térmico para ver posibles daños o fugas en las tuberías e impermeabilizante del techo del edificio, así mismo para daños en las celdas del panel solar.

Termograma 1:

En la figura 5 se observa la superficie exterior y el techo de la sede Bolívar, donde se aprecian colores más brillantes en las uniones del ducto de ventilación que sugieren posibles fugas, de igual manera en los marcos de la ventana se aprecian cambios en los gradientes térmicos que denotan una falta de aislamiento. El software Flir Tools, permite usar diferentes geometrías para la medición tales como puntos, círculos, líneas y cajas para analizar distintas secciones del termograma y cuyos resultados se despliegan de manera ordenada en tablas con valores de temperatura máxima y mínima, así como promedios de todos los valores que queden encerrados en las geometrías y/o sobre estas, también se registra la emisividad y temperatura aparente reflejada. En este termograma se utilizaron la herramienta Box (caja) para medir dos uniones del ducto, las cuales están señaladas con las flechas en la gráfica, esta herramienta permite determinar la temperatura más alta y baja dentro de la caja, y la diferencia de estos valores permitió determinar el gradiente térmico que indica una fuga. Como resultado del paso 3 se determinó que la temperatura reflejada es de 19°C y se configuró este parámetro en las cámaras. Por otro lado, como resultado de realizar el procedimiento del paso 4 se configuró un valor una emisividad de 0,93 que corresponde a la emisividad del bloque de ladrillo, 0,63 para el latón de los ductos y 0,93 para las ventanas, valores que la cámara tiene entre los parámetros configurables para cada material.. La técnica aplicada en este termograma fue termografía pasiva cuantitativa, en la figura 5 se relacionan los análisis con base en los valores de medición. El

termograma fue tomado con la cámara Flir E5.

Empresa	Fundación Universitaria los Libertadores	**Estándar:**	E ISO 18434
Descripción y ubicación	Bogotá, Barrios Unidos	**Cámara:**	FLIR E5
Equipo y elemento	Ducto de ventilación	**Fecha**	7 Junio 2022
Tipo de inspección	CUANTITATIVA	Hoja de reporte	1



ANALISIS TERMICO

Evaluación y diagnóstico: En los dos puntos de medición correspondientes a dos zonas de unión del ducto de ventilación hay una diferencia de 11°C y 5,4 °C respectivamente situación que es indicador de fugas de aire, con base en esos gradientes de temperatura que según las normas se clasifican como no aceptables. Se sugiere revisar las zonas de unión para corregir las fugas

SPOT	VALOR MEDIO
Emisividad	0.61
Distancia	10 m
Trefl	24°C
Bx 1	Max 33,9 °C – Min 22,9°C
	Diferencia 11°C
Bx 2	Max 30,5 °C – Min 25,1 °C
	Diferencia 5,4°C

Figura 5. Superficie exterior y el techo de la sede Bolívar

Fuente: Autores.

Termograma 2:

Exterior lateral del edificio Caldas. En la imagen térmica de la figura 6 se realizó un análisis cualitativo y se apreció un contraste térmico entre la ventana (color blanco y brillante) y el marco (color rojo amarillo opaco) porque no cuenta con aislamiento térmico, por lo tanto hay fugas de calor

apreciables que se evidencian con el gradiente térmico de 2,7 °C en el marco derecho de la ventana superior, medidos con la herramienta Box (caja), ocasionando que el interior del edificio sea bastante frio. El termograma fue tomado con el dron Parrot Anafi Thermal.

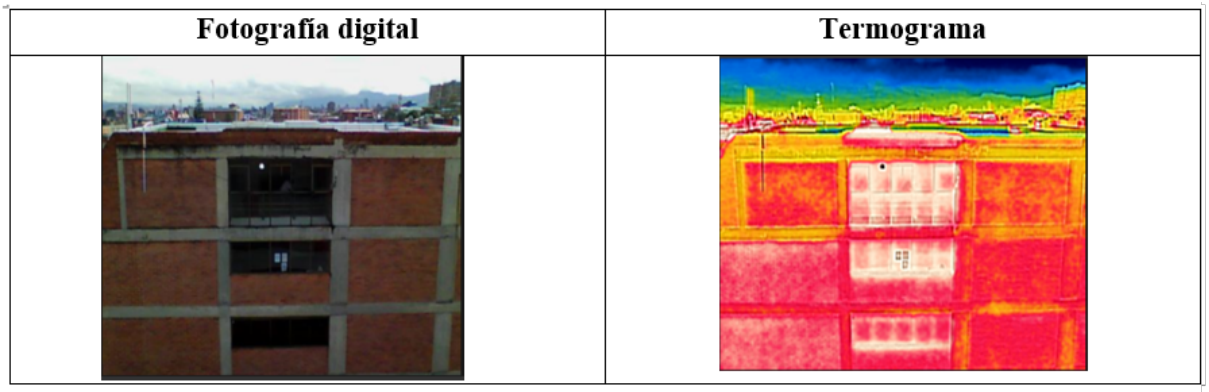


Figura 6. Fachada lateral exterior edificio Caldas.

Fuente: Autores.

Termograma 3:

Techo de la sede Caldas: en la figura 7 se observa un termograma obtenido con el Dron Parrot Anafi Thermal. El techo recientemente fue impermeabilizado y allí se ubica un panel solar. Mediante un análisis cualitativo se observa que el panel no presenta ningún daño en sus celdas ya que el tono es parejo en todas ellas. También se aprecia que el material utilizado para la impermeabilización conserva el calor que se genera por la radiación solar y es más opaco en las juntas ya que allí se utilizó una pintura de un tono mate.

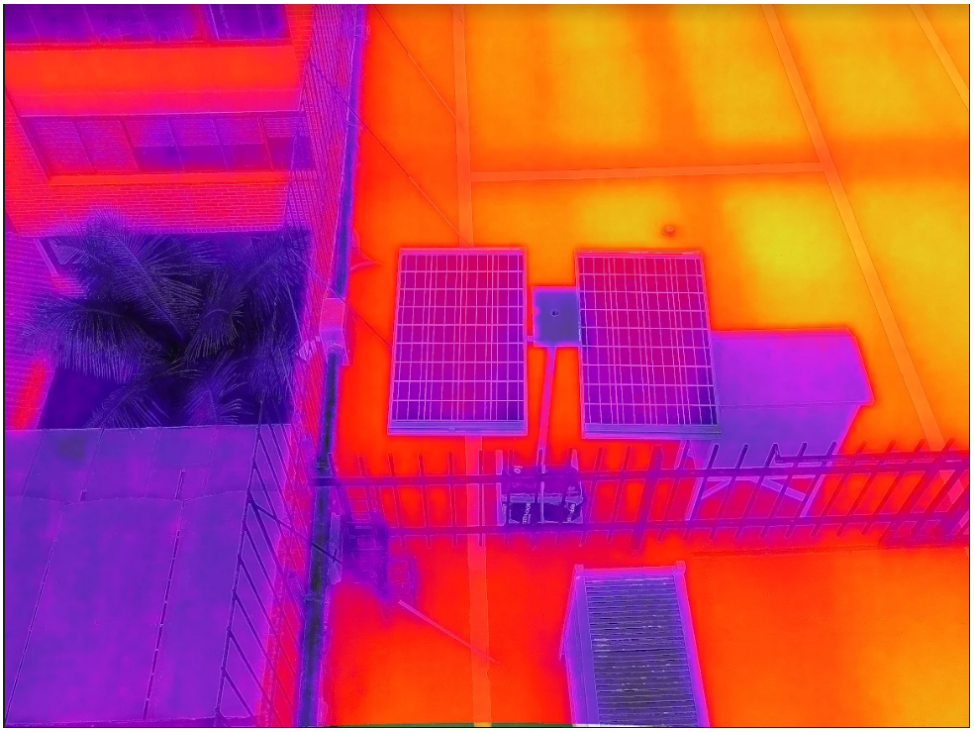


Figura 7. Techo edificio Caldas.

Fuente: Autores.

4. DISCUSIÓN

La termografía cualitativa permitió evidenciar fugas de calor en los ductos de ventilación mediante los gradientes térmicos mostrados en los termogramas, los cuales mostraron diferencias significativas en la unión de los ductos. Por otro lado, la termografía cuantitativa permitió observar fugas de calor en las uniones entre ventanas y en las uniones de estas con los marcos, en las que había diferencias de alrededor de 3°C grados, rango suficiente para evidenciar pérdidas de energía. La cámara en general mostró rangos de temperatura de entre 4 °C a 35 °C en todo el termograma, aunque estas diferencias se deben a los diferentes valores de emisividad térmica de los materiales, las medidas cuantitativas usando las herramientas del software Flir Tools permiten apreciar pérdidas de energía térmica en componentes específicos de la fachada y el techo; estas pérdidas deben evaluarse bajo los criterios de aceptación o rechazo definidos según las normas aplicables a cada caso o tipo de edificio y clima en el que se encuentre. En el caso de los ductos se usa la termografía cuantitativa debido a que

su valor de emisividad bajo de 0,63 hace que las medidas cuantitativas no sean del todo confiables, ya que una limitante de la técnica es que requiere valores de emisividad mayores a 0,8 para realizar termografía cuantitativa.

El uso de drones para realizar inspecciones de edificios ofrece varias ventajas, como la capacidad de acceder a áreas de difícil acceso y la reducción del tiempo y costo de las inspecciones. Se destaca la importancia de seguir las normas y estándares establecidos para la aplicación eficaz y confiable de la termografía infrarroja como método de inspección no destructivo. En general, los resultados de esta investigación sugieren que la termografía infrarroja aplicada con drones es una técnica prometedora para el análisis energético de edificios, que puede ayudar a mejorar la eficiencia energética y reducir los costos de operación de los edificios.

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https://revistas.udistrital.edu.co/index.php/Tecnura/issue/view/1201

DOI: https://doi.org/10.14483/22487638.20345

INVESTIGACIÓN

El conocimiento previo cultural como factor de influencia en la interculturalidad y movilidad estudiantil universitaria

Prior cultural knowledge as an influence factor on interculturality and university student mobility

Hernando Castro Garzón [1], Melissa Espinoza Elizondo [2], Vanessa Noelly Elizondo Villarreal [3]

Fecha de Recepción: 12 de enero de 2023 **Fecha de Aceptación**: 8 de julio de 2023

Cómo citar: Castro-Garzón, H., Espinoza-Elizondo, M. y Elizondo-Villarreal, V. N. (2023). El conocimiento previo cultural como factor de influencia en la interculturalidad y movilidad estudiantil universitaria. *Tecnura*, **27**(78), 172-184. https://doi.org/10.14483/22487638.20345

ABSTRACT

Universities have had to modify their processes to become competitive nationally and internationally. Student mobility has become a crucial element for institutional recognition, being a progressive and unequal phenomenon across continents, countries, and areas of study. Since 2010, this phenomenon has grown due to its relationship with the global academic and labor market, where students seek to strengthen their education and compete in the job market. The globalization phenomenon has been the main precursor of university student mobility, with significant growth in the number of international students between 2012 and 2017. However, the 2019-2021 pandemic reduced in-person mobility flows, leading institutions to venture into virtual mobility. Studies on student mobility reveal the importance of factors such as prior cultural knowledge, interculturality, and international school mobility. The research was conducted using qualitative methodology, including interviews with experts in academic mobility and interculturality. The results highlight the need for a comprehensive strategy that provides emotional security to students and considers their psychological profile when choosing a mobility destination.Keywords: culture, interculturality, mobility, cultural control theory.

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[1]Doctor en Desarrollo Sostenible, Magister en Gestión Ambiental Sostenible, Especialista en Salud Ocupacional, Especialista en Ecología y Medio Ambiente, profesional en Administración de Empresas Agropecuarias, profesor de la escuela de Administración y negocios, Facultad de Ciencias Económicas de la Universidad de los Llanos, Villavicencio, Colombia.
Email: hcastro@unillanos.edu.co

[2]Doctorante en Doctorado en Filosofía con Orientación en Relaciones Internacionales, Negocios y Diplomacia, Magister en Relaciones Internacionales, licenciada en Relaciones internacionales. Coordinadora de Servicio Social Facultad de Ciencias Políticas y Relaciones Internacionales, Universidad Autónoma de Nuevo León, Monterrey, México.
Email: melissa.espinozalz@uanl.edu.mx

[3]Doctorante en Doctorado en Filosofía con Orientación en Relaciones Internacionales, Negocios y Diplomacia, Magister en Relaciones Internacionales, licenciada en Relaciones internacionales. Auxiliar administrativo, Facultad de Ciencias Políticas y Relaciones Internacionales Universidad Autónoma de Nuevo León, Monterrey, México.
Email: Vanessa.elizondolz@uanl.edu.mx

Resumen

Las universidades han tenido que modificar sus procesos para lograr ser competitivas nacional e internacionalmente. La movilidad estudiantil se ha convertido en un elemento crucial para el reconocimiento de las instituciones, siendo un fenómeno progresivo y desigual entre continentes, países y áreas de estudio. Desde 2010, este fenómeno ha crecido debido a su relación con el mercado global académico y laboral, donde los estudiantes buscan reforzar su formación y competir en el mundo laboral. El fenómeno globalizador ha sido el principal precursor de la movilidad estudiantil universitaria, con un crecimiento significativo en el número de estudiantes internacionales entre 2012 y 2017. Sin embargo, la pandemia de 2019-2021 redujo los flujos de movilidad presencial, llevando a las instituciones a incursionar en la movilidad virtual. Los estudios sobre la movilidad estudiantil revelan la importancia de factores como el conocimiento previo cultural, la interculturalidad y la movilidad escolar internacional. La investigación se realizó con metodología cualitativa, incluyendo entrevistas a expertos en movilidad académica e interculturalidad. Los resultados resaltan la necesidad de una estrategia integral que brinde seguridad emocional a los estudiantes y considere su perfil psicológico al elegir un destino de movilidad.
Palabras clave: Cultura, interculturalidad, movilidad, teoría del control cultural.

1. Introducción

Las universidades han tenido que modificar sus procesos para lograr ser competitivas nacional e internacionalmente (Ariño Villarroya, A. et al. (2014).); la movilidad estudiantil es uno de esos elementos que hacen parte del reconocimiento de las instituciones, convirtiéndose desde el 2010 en un evento progresivo y desigual entre continentes, países y áreas de estudio, debido a la relación directa que tiene con el mercado global académico y laboral (Vázquez, M. G. V. (2014).), en donde los estudiantes buscan reforzar, experimentar, entender y competir con su formación, en la búsqueda de dar valor agregado a su curriculum en el momento de hacer parte de la clase trabajadora de la nación en la cual se encuentran.

La movilidad estudiantil se podría definir como "estancias de estudio en un país extranjero de una duración mínima de un semestre" (Ariño Villarroya, A. et al. (2014).), es de aclarar que se pueden desarrollar diversos modos de movilidad universitaria, tales como aquellas que están parametrizadas bajo acuerdos de movilidad entre instituciones ya sean de carácter nacional, regional o internacional (Luchilo, L. (2006).), otra de estas modalidades son las que toman los estudiantes de forma libre, es decir, en donde no hay una relación formal entre las instituciones, tan solo un interés del susodicho para realizar allí su estancia, finalmente está la movilidad que se realiza pensada en el área de estudio y el lugar en donde se encuentra la institución de interés (Aguirre, F. et al. (2018).).

Esta interacción de los estudiantes hacia el entorno exterior además de enriquecer las experiencias de vida y brindar valor en su curriculum académico, trae consigo unos indicadores de competitividad, calidad y posibilidad de empleabilidad (Bonilla-Jurado, D. M. et al. (2019).), así como reconocimiento a las instituciones que apoyan a estos estudiantes en su interés de diversificar sus áreas de oportunidad.

El fenómeno globalizador ha sido el principal precursor de la movilidad estudiantil universitaria, debido a la apertura de fronteras y la liberación de conocimiento, el cual ahora debe de estar estructurado desde diferentes prismas, sociales, culturales, económicos, políticos, geográficos, etc. (Rabossi, M. & Guaglianone, A. (2020).), y es de esta manera como en el mundo el flujo de estudiantes universitarios fue para el 2012 de 198 millones y para el 2017 de 220 millones, lo cual representó un crecimiento del 10 %, esta cifra en Latinoamérica y el Caribe ha tenido un impacto mayor ya que se pasó de 23,7 millones en el 2012 a 27.4 millones en el 2017, a continuación se adjuntan tres gráficos publicados por la Unesco en cuanto a la movilidad universitaria.

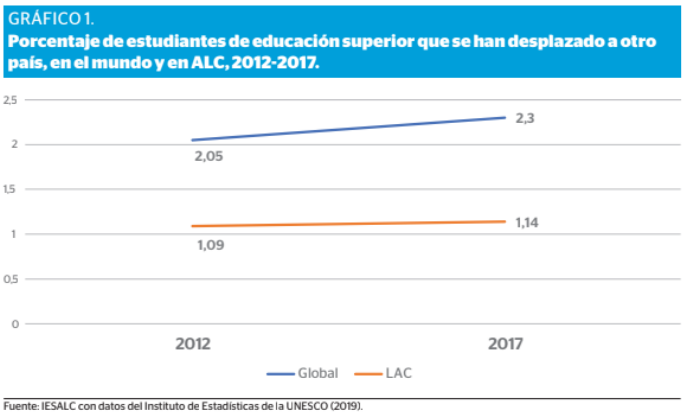

Figura 1. Porcentaje de estudiantes de educación superior que se han desplazado a otro país, en el mundo y en ALC, 2012-2017.

Fuente: *IESALC con datos del instituto de Estadisticas de la UNESCO (2019)*

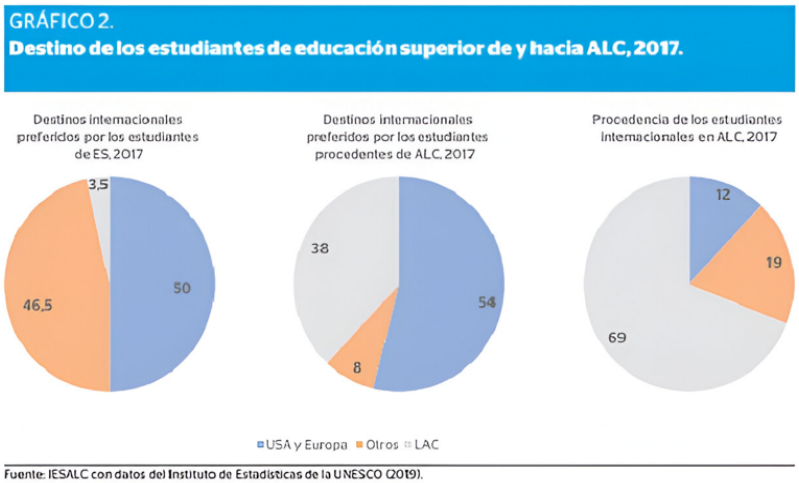

Figura 2. Destino de los estudiantes de educación superior de y hacia ALC, 2017.

Fuente: *IESALC con datos del Instituto de Estadísticas de la UNESCO (2019)*

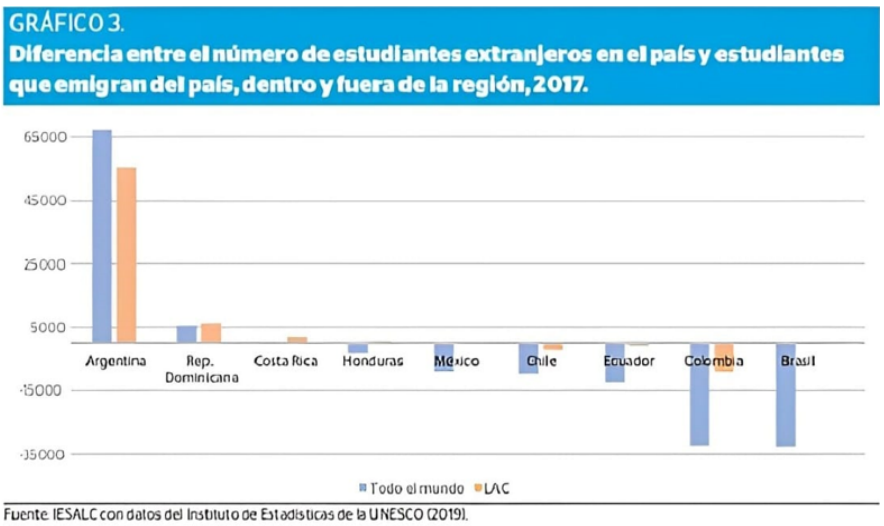

Figura 3. Diferencia entre el número de estudiantes extranjeros en el país y estudiantes que migran del país, dentro y fuera de la región, 2017.

Fuente: *IESALC con datos del Instituto de Estadísticas de la UNESCO (2019)*

En las tres gráficas presentadas se logra evidenciar el crecimiento que ha desarrollado la movilidad universitaria durante desde el 2012 al 2017, así como los países más visitados por los estudiantes para desarrollar su movilidad, siendo Estados Unidos y Europa los de mayor porcentaje, y en segundo lugar otros destinos los cuales hacen referencia a Australia, Malta, Marruecos y países de asiáticos en

último lugar se encuentra Latinoamérica y el Caribe (LAC). Finalmente, la tercera gráfica permite observar que dentro de la región LAC el país con mayor afluencia de estudiantes extranjeros es Argentina (Rodríguez-Rodríguez, M. D. & Dominguez Mujica, J. (2019).) con un porcentaje muy por encima a los demás países, los cuales en su mayoría se encuentran por debajo de la línea horizontal demarcando un proceso contrario a la recepción, es decir, que el flujo de movilidad de estudiantes universitarios de países como Colombia y Brasil buscan envía más estudiantes al exterior del que suelen recibir.

Debido a la pandemia que afecto a la humanidad durante el 2019 al 2021, los flujos de movilidad universitaria presencial disminuyeron en un 35 % en países como Estados Unidos, 25 % Europa y 28 % Australia (Rios-Campos, C. et al. (2022).), afectados igualmente por el cierre de matrículas, fronteras y aeropuertos a nivel mundial, como respuesta las instituciones incursionaron en un proceso denominado movilidad virtual (Gaytán-Oyarzun, J. C. et al. (2022).), el cual requería del mismo proceso de petición y recepción de estudiantes en un formato digital.

Ahora bien, estos procesos de movilidad están dados por factores de interés tanto de las instituciones de educación como de los estudiantes, tales como calidad en el área de conocimiento (Rodríguez-Pérez, M. V. et al. (2018).) en el cual se encuentra formándose el estudiante, para incentivar la educación y la investigación, la homologación de conocimiento. El interés de realizar una contribución a la sociedad desde el ámbito personal e institucional (de Wit, Hunter, Howard, & Egron-Polak, 2015, citado por Gacel-Ávila y Rodriguez-Rodriguez, 2018, p. 24), y finalmente la intención de desarrollar un intercambio internacional, intercultural y global, es en este parámetro en cual se centra esta investigación.

A pesar de la importancia del tema de la movilidad académica, sólo un conocimiento parcial o limitado considera las dimensiones de este fenómeno y sus implicaciones. Aunque organismos internacionales como la UNESCO, la OCDE o la Organización de los Estados Americanos (OEA) aportan estadísticas sobre la movilidad estudiantil, todavía hay poca investigación sobre las trayectorias educativas de estos estudiantes, sus motivaciones para la toma de decisiones relacionadas con los países a los que aspiran y las instituciones en las cuales (Woodley, S. et al. (2019).) se realizan los estudios, y el grado en que se integran dentro de dichas instituciones (Konopyanova, G. et al. (2018).). En otras palabras, la demografía no revela algunas de las peculiaridades de la movilidad estudiantil, como las

mencionadas anteriormente. Existen varios autores que realizan sus investigaciones sobre la importancia de la movilidad universitaria para el desarrollo y crecimiento tanto de los estudiantes como de las mismas instituciones (Mendoza, C. et al. (2016).) aun así los estudios teóricos son escasos.

Jumma 1981 realizó un estudios en el cual analizaba los factores que influían en la decisión de ir a un país o al otro, dicho estudio se realizó en estudiantes franceses, como resultado de la investigación obtuvieron que en primer lugar y el más importante de los factores era la imagen que tenían del país, en segundo lugar el conocimiento y manejo del idioma, en tercer lugar el tener amigos o familiares en dicho país, en cuarto lugar la calidad de la enseñanza y la gratuidad en los programas de interés, finalmente y como factor sorpresa el rechazo cultural a los Estados Unidos de Norte América.

De igual forma (Paivandi, S. (1991).), realizó un estudio idéntico al de Jumma en estudiantes Iranies, para lograr determinar los factores que influyen en la elección de un país para realizar movilidad académica, a diferencia de los estudiantes fraceses, los iranies hacen especial referencia en la facilidad de los trámites migratorios, así como la aceptación de su cultura en el país de destino, en segundo lugar el conocimiento previo del país, la libertad universitaria y finalmente la presencia de amigos y familiares en dicho país, factores similares a los planteados por (Viguier, M. C. (1966).), en donde el origen geográfico es la variable sobresaliente acompañado del componente cultural.

Los nuevos estudios toman variables más amplias y acordes a la actualidad, es el caso de (Coulon, A. et al. (2003).), quienes clasifican los factores en dos grupos, el primero de ellos está determinado por el agente institucional y el ambienta tales el renombre de la institución a la que se pretende movilizar, la calidad, las técnicas de enseñanza, el peso académico del diploma a obtener en esa institución, la oferta de becas y facilidad del trámite, la comprensión del idioma, el conocimiento cultural, social y político del país así como la imagen positiva del mismo. el segundo grupo consta de los factores internos que llevan a los estudiantes a tomar la decisión de experimentar un proceso de movilidad, tales como la calidad de las universidades locales, las cuales determinan los estudiantes como no muy buena, la poca oferta académica en determinadas áreas del conocimiento, la escasa especialización en áreas determinadas, el punto de vista y consejo de los padres o familiares en formarse en país diferente debido a escenarios tales de guerra, crisis social o política, trance social y desabasto económico.

Autores como (Gómez Monfort, L. et al. (2010).), (Ngoupandé, J. P. (1995).) y (Borgogno, V. et al.

(1998).), con investigaciones hechas a estudiantes provenientes de Latinoamérica hacia la universidad de Valencia en España y estudiantes de países africanos, hacen énfasis en el contexto tanto social, político, geográfico, económico y cultural como determinantes en la decisión de movilidad hacia no solo otro país si no un continente diferente.

2. METODOLOGÍA

Esta investigación se realizó con metodología cualitativa, usando herramientas como la entrevista semiestructurada a profundidad; para la cual se realizó el cálculo de la muestra a través del proceso no probabilístico tomando como referencia las universidades que presentan mayor número de estudiantes internacionales provenientes de la Universidad Autónoma de Nuevo León, así como también personas con consultorías para la negociación e interculturalidad.

Las categorías de análisis fueron el conocimiento previo cultural, la interculturalidad y movilidad escolar internacional, las cuales se llevaron a cabo en todas las entrevistas, siendo estas a expertos en el tema de movilidad académica e interculturalidad de instituciones tales como Teisva, la Universidad Autónoma de Nuevo León, la Rochat School of business y el Instituto Tecnológico de Estudios Superiores de Monterrey.

3. RESULTADOS

Se obtuvieron los siguientes resultados

Figura 4. Nube de palabras de la categoría Conocimiento previo cultural.

Fuente: *Autores. Imagen obtenida de NVivo.*

En la imagen se logra apreciar la nube de palabras en la cual se visualiza las que son usadas con frecuencia por los entrevistados, así las cosas, "cultura" es la de mayor representación, seguido por "similitud" y "sociales" lo cual permite observar semejanzas con investigaciones previas analizadas en la teoría, de igual forma es interesante observar las palabras "pláticas" e "informativas" puesto que estas denotan la importancia de consultar información previa al tomar la decisión de realizar un intercambio, así como la asistencia a charlas informativas por parte tanto de las instituciones como de los estudiantes que han desarrollado experiencias previas y son compartidas por los interesados.

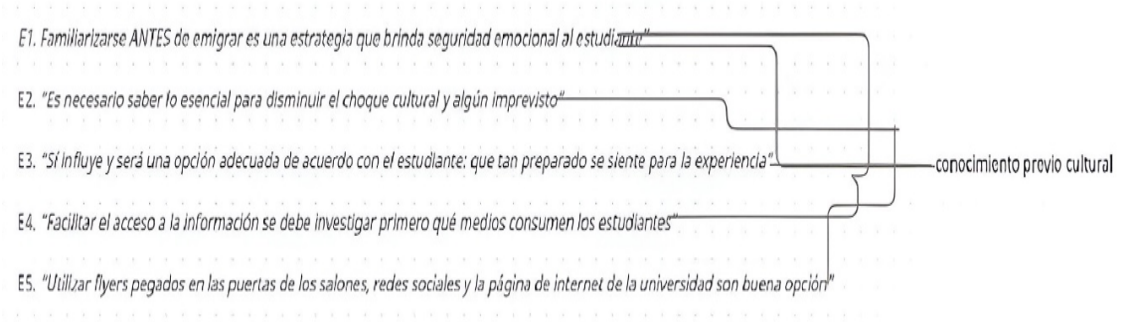

Figura 5. Árbol de palabras de la categoría/nodo conocimiento previo cultural

Fuente: *Autores. Imagen obtenida de NVivo.*

Los entrevistados indicaron que los estudiantes que realizan movilidad académica deberán de tener conocimiento previo cultural enfocado hacia las costumbres y tradiciones del país receptor, sin embargo, los coordinadores de movilidad académica y estudiantes necesitan evitar en medida de lo posible el choque cultural. Por lo tanto, proponen que las instituciones establezcan una estrategia que brinde seguridad emocional al estudiante, misma que ayuda a reducir el estrés causado por lo desconocido o la incertidumbre, dentro de estas actividades destacan los talleres gastronómicos, históricos, proyección de películas y ejemplificar los choques culturales más comunes en el país receptor. Por otra parte, los entrevistados mencionan que depende del objetivo de la movilidad es la recomendación que dan para que la movilidad sea en un país con baja similitud cultural y poder así enriquecer el intercambio.

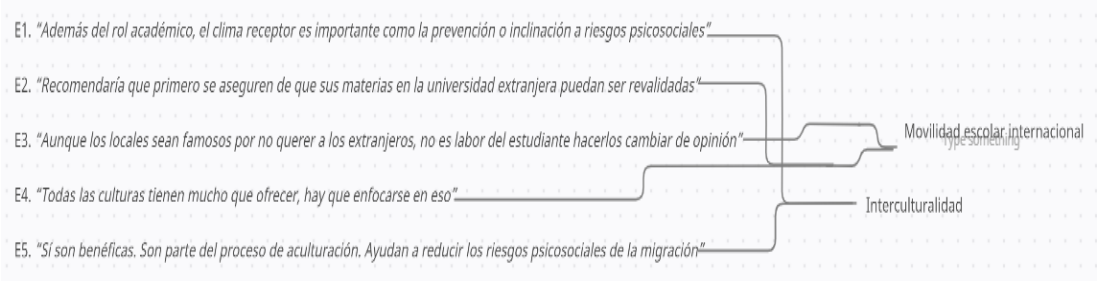

Figura 6. Árbol de palabras de la categoría/nodo movilidad escolar internacional e interculturalidad

Fuente: *Autores. Imagen obtenida de NVivo.*

En relación a los nodos desarrollados por las categoría de movilidad escolar internacional e interculturalidad permiten apreciar la relación entre las diferentes afirmaciones realizadas por los entrevistados, ejemplo de ello: sí el país receptor es líder en el campo de estudio, poco importará si la afinidad cultural del país receptor es alta o baja; también es importante considerar el perfil psicológico del estudiante, es decir, sí éste tiene problemas de ansiedad o poca predisposición a adaptarse al cambio, entonces un país con afinidad muy diferente afectaría el rendimiento académico y la experiencia intercultural. Finalmente, los expertos aseguran que es indispensable que el estudiante cuente con la información disponible sobre los programas de movilidad académica a través de redes sociales y pláticas informativas.

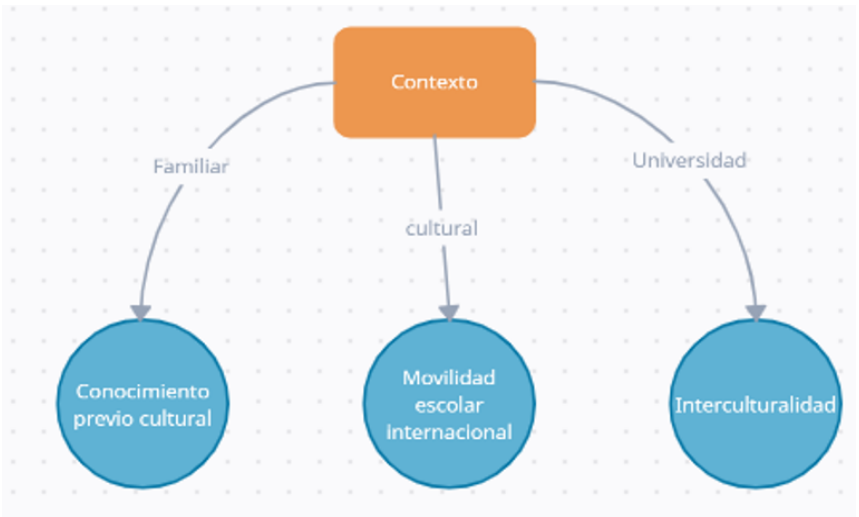

Figura 7. Mapa mental de categorías y nodos.

Fuente: *Autores. Imagen obtenida de NVivo.*

En la figura 7 se observa los nodos relevantes en cuanto a cada categoría de análisis, permitiendo entender para los entrevistados según su experiencia, así las cosas, el conocimiento previo cultural tiene una relación directa por el factor familiar, es decir, los estudiantes toman la decisión del país a donde emigrar con apoyo y opinión de sus familiares más cercanos, tomando como sugerencia las experiencias de amigos y conocidos que se encuentren en el país receptor. En cuanto a la movilidad escolar, está determinada por la cultura; así, el idioma, la gastronomía, las festividades, la creencia religiosa, el contexto político y el desarrollo económico del país son determinantes en la selección del estudiante. Finalmente, en cuanto a la interculturalidad la institución universitaria y su prestigio son el factor concluyente ya que el área de estudio, la especialidad, el renombre de la misma y hasta la formación de los docentes son definitivos en el momento de tomar la decisión de movilizarse.

4. CONCLUSIONES

La evolución de la movilidad estudiantil en la educación superior refleja una tendencia global hacia una mayor competitividad y reconocimiento entre las instituciones. Este fenómeno, impulsado por la demanda de mano de obra calificada en los mercados académicos y laborales globales, ha experimentado un crecimiento significativo desde 2010, con un impacto notable tanto en regiones desarrolladas como en desarrollo.

La pandemia de COVID-19, si bien ha interrumpido los patrones tradicionales de movilidad presencial, aceleró la adopción de la movilidad virtual como alternativa. Este cambio subrayó la importancia de la adaptabilidad y la resiliencia ante desafíos imprevistos, llevando a las instituciones a explorar nuevos enfoques para mantener conexiones internacionales y oportunidades educativas.

La conciencia cultural y la competencia intercultural surgen como factores críticos que influyen en las decisiones y experiencias de movilidad estudiantil. Las instituciones deben priorizar estrategias que fomenten la seguridad emocional y el apoyo para los estudiantes que navegan por paisajes culturales desconocidos, al mismo tiempo que promueven la comprensión y colaboración intercultural dentro de las comunidades académicas.

A pesar del progreso realizado en la comprensión de los impulsores e implicaciones de la movilidad estudiantil, sigue habiendo necesidad de más investigación para explorar completamente los matices de este fenómeno complejo. Al profundizar en las motivaciones, experiencias y resultados de los

estudiantes móviles, los académicos pueden informar políticas y prácticas más efectivas que mejoren los beneficios educativos y sociales de la movilidad internacional para individuos e instituciones por igual.

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CONTENIDO

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- Si se desea resaltar palabras o frases del texto, no usar letra negrita sino letra cursiva.
- Los decimales se deben señalar con coma (,) y no con un punto.
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- Evitar las notas de pie de página.
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- Información de los autores.
- Resumen en español e inglés.
- Palabras clave en español e inglés.
- Introducción.
- Conclusiones.
- Trabajo futuro (opcional).
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- Referencias bibliográficas.

Si el artículo es de investigación científica y tecnológica deben tener, además de lo anterior, los siguientes componentes:

- Metodología.
- Resultados.
- Financiamiento.

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El título del artículo deberá ser corto o dividido en título y subtítulo, atractivo para el lector potencial y escrito en mayúscula sostenida. Este debe aparecer centrado entre las márgenes, escrito con letra *Times New Roman*, en negrita, tamaño de fuente 18. El título del artículo debe ir en español e inglés separado por un espacio doble. Máximo 20 palabras.

Autores

Después del título debe escribirse el (los) nombre(s) completo(s) del (los) autor(es), acompañado de

los datos biográficos básicos: título de pregrado, título de posgrado, ocupación o cargo, afiliación institucional (institución donde labora), dependencia, ciudad, país y correo electrónico. La información anterior debe ir inmediatamente debajo del nombre del autor.

Resumen

Debe establecer el objetivo y alcance del trabajo, una descripción clara y concisa de la metodología, los resultados y las conclusiones obtenidas. Máximo 250 palabras.

Palabras clave

Debe escogerse entre tres y diez palabras clave, escritas en español con letra *Times New Roman*, en negrita y cursiva.
Las palabras clave deben estar escritas en orden alfabético y ser de uso estandarizado, para lo cual se sugiere utilizar bases de datos internacionales según el área del conocimiento. Por ejemplo, en el área de Eléctrica y Electrónica se sugiere utilizar el tesauro de la UNESCO que se pueden encontrar en la página: http://databases.unesco.org/thessp.

Abstract

Debe ser una traducción correcta y precisa al idioma inglés del texto que aparece en el resumen en español.

Keywords

Debe ser una traducción correcta y precisa al idioma inglés de la lista de palabras clave en español.
Las *keywords* deben estar escritas en el orden de las palabras clave y ser de uso estandarizado, para lo cual se sugiere utilizar bases de datos in- ternacionales según el área del conocimiento. Por ejemplo, en el área de Eléctrica y Electrónica se sugiere utilizar los Tesauros de la IEEE y/o World Bank que se pueden encontrar en las siguientes páginas respectivamente: http://www.ieee.org/documents/2009Taxonomy_v101.pdf, http://multites.net/mtsql/wb/site/default.asp

Introducción

Debe describir el planteamiento general del trabajo, así como contexto, antecedentes, estado de arte de la temática abordada, objetivo y posible alcance del trabajo.

Metodología

La redacción de este apartado debe permitir a cualquier profesional especializado en el tema replicar

la investigación.

Resultados
Explicación e interpretación de los hallazgos. Si es necesario, se puede presentar una discusión breve y enfocada a la interpretación de los resultados.

Conclusiones
Implicación de los resultados y su relación con el objetivo propuesto.
Financiamiento
Mencionar la investigación asociada de la cual se derivó el artículo y la entidad que avaló y financió dicha investigación.

Agradecimientos
Preferiblemente deben ser breves y deben incluir los aportes esenciales para el desarrollo del trabajo.

Ecuaciones
Deben aparecer centradas con respecto al texto principal. Las ecuaciones deben ser referenciadas con números consecutivos (escritos entre paréntesis cerca al margen derecho). Las ecuaciones se citan en el texto principal empleando la palabra ecuación y seguida del número entre paréntesis. Las ecuaciones deben ser elaboradas en un editor de ecuaciones apropiado y compatible con el paquete de software InDesign, por ejemplo, el editor de ecuaciones de Windows.

Tablas
Para el caso de realización de tablas se recomienda que estas no sean insertadas como imágenes, considerando que en este formato no pueden ser modificadas. El encabezado de cada tabla debe incluir la palabra Tabla (en negrita) seguida del número consecutivo correspondiente y de un breve nombre de la tabla. El encabezado debe estar escrito con letra Times New Roman, en cursiva y tamaño de fuente 9.
No se presentan cuadros sino tablas y estas se deben levantar automáticamente desde el procesador de textos. Las tablas deben ir nombradas y referenciadas en el artículo, en estricto orden. Toda tabla debe tener en su parte inferior la fuente de la que fue tomada, o mencionar que es autoría de los autores si es el caso.

Figuras
Todas las figuras o fotografías deben enviarse en formato PNG o TIFF con una resolución mínima de 300 DPI, adaptadas a escala de grises.

El pie o rótulo de cada figura debe incluir la palabra Figura (en negrita) seguida del número consecutivo correspondiente y de una breve descripción del contenido de la figura. El pie de figura debe estar escrito con letra Times New Roman, en cursiva y tamaño de fuente 9. Las figuras deben ir nombradas y referenciadas en el artículo, en estricto orden. Toda figura debe tener también la fuente de la que fue tomada, o mencionar que es autoría de los autores si es el caso.

Símbolos

Los símbolos de las constantes, variables y funciones en letras latinas o griegas –incluidos en las ecuaciones– deben ir en cursiva; los símbolos matemáticos y los números no van en cursiva. Se deben identificar los símbolos inmediatamente después de la ecuación. Se deben utilizar las unidades, dimensiones y símbolos del sistema internacional.

Cuando se empleen siglas o abreviaturas, se debe anotar primero la equivalencia completa, seguida de la sigla o abreviatura correspondiente entre paréntesis y en lo subsecuente se escribe solo la sigla o abreviatura respectiva.

Referencias bibliográficas

El estilo de citación de referencias adoptado por la revista Tecnura es APA sexta edición. Las citas, referencias bibliográficas e infografía se incluyen al final del artículo. Las referencias bibliográficas deben ordenarse alfabéticamente de acuerdo con el primer apellido del primer autor, sin numeración. Solo deben aparecer las referencias que fueron citadas en el texto principal del trabajo, en las tablas o en las figuras. Es decir, en la lista no deben aparecer otras referencias aunque hayan sido consultadas por los autores para la preparación del trabajo. Sugerimos utilizar herramientas como: *Citas y bibliografía de Microsoft Word* (para APA sexta edición versión 2013 o superior), *Zotero, Mendeley*, entre otras.

El llamado de una referencia bibliográfica se inserta en el texto, en el punto pertinente, bajo ciertas características:

- Si la oración incluye el apellido del autor, solo se debe escribir la fecha dentro de un paréntesis, ejemplo:

  Cuando Vasco (2012), analizó el problema de presentado en ....

- Cuando no se incluye el autor en la oración, debe ir entre el paréntesis el apellido y la fecha. La investigación de materiales dio una visión en el área (Martínez, 2012).

- Si el documento u obra tiene más de dos autores, se debe citar la primera vez con todos los apellidos. 1990. (Fernández Morales, Villa Krieg & Caro de Villa, 2008) ....

- En las menciones siguientes, solo se debe escribir el primer apellido del autor, seguido de un "et al". En cuanto al estudio de las aguas, Fernández Morales et al. (2008) encontraron que ...
- Cuando el documento u obra tiene más de seis autores, se debe utilizar desde la primera mención el "et al".

A continuación se describen una serie de ejemplos de las referencias más utilizadas, según el estilo de referencias adoptado por la revista Tecnura:

Publicaciones Periódicas:

Forma Básica

Apellidos, A. A., Apellidos, B. B. & Apellidos, C. C. (Fecha). Título del artículo. Título de la publicación, volumen (número), pp. xx-xx. doi: xx.xxxxxxx

Artículo básico

Guevara López, P., Valdez Martínez, J., Agudelo González, J., & Delgado Reyes, G. (2014). Aproximación numérica del modelo epidemiológico SI para la propagación de gusanos informáticos, simulación y análisis de su error. Revista Tecnura, 18(42), 12 -23. doi: http://dx.doi.org/10.14483/udistrital.jour.tecnura.2014.4.a01

Artículo web

Rodríguez Páez, S., Fajardo Jaimes, A., & Páez Rueda, C. (2014). Híbrido rat-race miniaturizado para la banda ISM 2,4 GHZ. Revista Tecnura, 18(42), 38-52. Recuperado de http://revistas.udistrital.edu.co/ojs/index.php/Tecnura/article/view/8059/9675

Libros:

Forma Básica

Apellidos, A. A. (Año). Título. Ciudad: Editorial.
Apellidos, A. A. (Año). Título. Recuperado de http://www.xxxxxx.xxx
Apellidos, A. A. (Año). Título. doi: xx.xxxxxxxx
Apellidos, A. A. (Ed.). (Año). Título. Ciudad: Editorial.

Libro con autor

Goleman, D. (2000). La inteligencia emocional: Por qué es más importante que el cociente intelectual. México: Ediciones B.

Libro con editor

Castillo Ortiz, A. M. (Ed.). (2000). Administración educativa: Técnicas, estrategias y prácticas gerenciales. San Juan: Publicaciones Puertorriqueñas

Libro versión electrónica:

Montero, M. & Sonn, C. C. (Eds.). (2009). Psychology of Liberation: Theory and applications. [Versión de Springer]. doi: 10.1007/ 978-0-387-85784-8

Informe técnico

Forma Básica

Apellidos, A. A. (Año). Título. (Informe Núm. xxx). Ciudad: Editorial

Informe con autores

Weaver, P. L., & Schwagerl, J. J. (2009). U. S. Fish and Wildlife Service refuges and other nearby reserves in Southwestern Puerto Rico. (General Technical Report IITF-40). San Juan: International Institute of Tropical Forestry.

Informe de una agencia del gobierno

Federal Interagency Forum on Child and Family Statistics. America's Children: Key National Indicators of Well-Being, 2009. Washington, DC: U.S. Government Printing Office. Recuperado de http://www.childstats.gov/pubs/index.asp

Tesis

Forma Básica

Apellidos, A. A. (Año). Título. (Tesis inédita de maestría o doctorado). Nombre de la institución, Localización.

Tesis inédita, impresa

Muñoz Castillo, L. (2004). *Determinación del conocimiento sobre inteligencia emocional que poseen los maestros y la importancia que le adscriben al concepto en el aprovechamiento de los estudiantes*. (Tesis inédita de maestría). Universidad Metropolitana, San Juan, PR.

Tesis de base de datos comercial

Santini Rivera, M. (1998). *The effects of various types of verbal feedback on the performance of selected motor development skills of adolescent males with Down syndrome*. (Tesis doctoral). Disponible en la base de datos ProQuest Dissertations and Theses. (AAT 9832765).

Tesis web

Aquino Ríos, A. (2008). *Análisis en el desarrollo de los temas transversales en los currículos de es- pañol, matemáticas, ciencias y estudios sociales del Departamento de Educación.* (Tesis de maestría, Universidad Metropolitana). Recuperado de http://suagm.edu/umet/biblioteca/UMTESIS/Tesis_Educacion/ARAquinoRios1512.pdf

Estándares o patentes

Forma Básica

Apellidos, A. A. Título de la patente. País y número de la patente. Clasificación de la patente, fecha de concesión oficial. Número y fecha de solicitud de la patente, paginación.

Hernández Suárez, C. A., Gómez Saavedra, V. A., & Peña Lote, R. A. Equipo medidor de indicadores de calidad del servicio de energía eléctrica para usuario residencial. Colombia., 655. G4F 10/0, 15 de Marzo 2013. 27 de Octubre 2011, 147

ENVÍO DE ARTÍCULOS

Los autores deben enviar sus artículos a través de la aplicación para tal fin del Open Journal System en formato digital, adjuntando la carta de presentación y el formato de información artículo-autores.

Carta de presentación

El artículo debe ir acompañado de una carta de presentación dirigida al director y editor de la revista, Ing. Cesar Augusto García Ubaque, donde incluya:

- Solicitud expresa de considerar su artículo para publicarlo en la revista Tecnura.
- Título completo del trabajo.
- Nombres completos de todos los autores del trabajo.
- Certificación de la originalidad y el carácter inédito del trabajo.
- Exclusividad de su remisión a la revista Tecnura.
- Confirmación de la autoría con la firma de todos los autores.

Esta carta deberá estar firmada por todos los autores, escanearse y enviarse junto con los demás documentos solicitados.

Formato de información artículo-autores

El artículo además debe ir acompañado de un formato de información sobre el artículo y sus autores, el cual se puede descargar de la página web de la revista Tecnura: https://revistas.udistrital.edu.co/index.php/Tecnura/formatos_documentos, en la sección "Formatos

y Documentos". Es importante completar todos los campos de información solicitados, algunos de ellos tienen comentarios para aclarar mejor lo que se está solicitando. El formato no debe escanearse.

Artículo

Artículo en formato digital (Word 2003 en adelante) que cumpla con todas las normas de presentación descritas en el capítulo 3, "Formato del artículo", de la presente en las instrucciones a los autores.

PROCEDIMIENTO PARA LA PUBLICACIÓN

El procedimiento que sigue la revista Tecnura para la evaluación y posible publicación de los trabajos enviados por los autores es el siguiente en orden cronológico:

1. Envío del articulo acompañado de la carta de presentación y el formato de información por parte de los autores.
2. Notificación al autor de correspondencia de la recepción del artículo.
3. Verificación del tema del artículo con respecto a las áreas de interés de la revista.
4. Verificación de las normas de presentación por parte del monitor de la revista.
5. Notificación al autor de correspondencia de la evaluación de las normas de presentación.
6. Envío de las correcciones realizadas por los autores con respecto a la evaluación de las normas de presentación
7. Envío del artículo a los árbitros seleccionados.
8. Notificación del inicio del proceso de arbitraje del artículo.
9. Notificación a los autores de la decisión tomada por el Comité Editorial y de las evaluaciones hechas por los árbitros.
10. Envío de las correcciones realizadas por los autores con respecto a las evaluaciones de los árbitros.
11. Estudio de la versión final del artículo y de las evaluaciones de los árbitros por parte del Comité Editorial.
12. Envío por parte de los autores de la carta de cesión de derechos al editor de la revista.
13. Envío de la versión con corrección de estilo y diagramada a los autores.
14. Verificación de errores y aprobación final de la versión con corrección de estilo y diagramada por parte de los autores.

15. Publicación del artículo en el número correspondiente de la revista Tecnura.

16. Notificación a los autores de la publicación del número de interés.

17. Envío de un ejemplar de la revista a cada autor del artículo publicado.

PROCESO DE ARBITRAJE DE ARTÍCULOS

Considerando la periodicidad trimestral de la revista, el Comité Editorial realiza cuatro convocatorias anuales para la recepción de artículos, aproximadamente en los meses de febrero, mayo, agosto y noviembre. Los artículos serán recibidos hasta la fecha máxima establecida en cada convocatoria.
Una vez recibidos los artículos el monitor de la revista realizará una primera evaluación de forma para verificar que cumplan con todos los elementos mencionados en esta guía de instrucciones a los autores. Luego de recibir nuevamente el articulo con las correcciones de forma solicitadas por el monitor de la revista, este será sometido a evaluación por tres pares académicos (paulatinamente se espera incorporar un mayor número de pares externos que participen en el proceso).
Cada artículo remitido a la revista Tecnura es revisado por dos pares académicos externos a la institución de los autores, mediante un proceso de "revisión entre pares" (*Peer-review*) de doble-ciego, garantizando el anonimato de los autores y evaluadores; se considera confidencial todo trabajo recibido y así se le exige a sus evaluadores.
Las posibles conclusiones de los resultados de la evaluación por parte de los árbitros son únicamente tres: publicar el artículo sin modificaciones, publicar el artículo con modificaciones o no publicar el artículo.
Posteriormente, el Comité Editorial toma la decisión de publicar o no los artículos, con base en los resultados de las evaluaciones realizadas por los árbitros asignados. En caso de existir contradicciones en las evaluaciones con respecto a la publicación de un artículo, el Comité Editorial enviará el artículo a un tercer árbitro y se inclinará por las dos evaluaciones que tengan el mismo concepto respecto a la publicación del artículo.
En cada convocatoria el autor de correspondencia debe sugerir al menos cuatro posibles evaluadores externos a su institución laboral, los cuales deben ser especialistas en el tema específico del artículo remitido, tener al menos maestría y por lo menos dos deben ser internacionales. Los posibles evaluadores pueden pertenecer a una universidad o industria, pública o privada; de estos se debe proporcionar el nombre completo, su formación académica más alta, su afiliación institucional y su correo electrónico. Estos cuatro potenciales evaluadores serán analizados por el Comité Editorial a fin de ampliar la base de datos de los árbitros de la revista Tecnura.
El Comité Editorial de la revista Tecnura se reserva los derechos de impresión, reproducción total o parcial del artículo, así como el de aceptarlo o rechazarlo. Igualmente, se reserva el derecho de hacer

cualquier modificación editorial que estime conveniente; en tal caso el autor recibirá por escrito recomendaciones de los evaluadores. Si las acepta, deberá entregar el artículo con los ajustes sugeridos dentro de las fechas fijadas por la revista para garantizar su publicación dentro del número programado.

CONTACTO

Para cualquier solicitud de información adicional puede comunicarse a través del correo electrónico de la revista Tecnura: tecnura@udistrital.edu.co, o por mensajería con el Dr. Alexander Jiménez Triana, Director y Editor de la revista Tecnura, a la dirección:

Revista Tecnura
Sala de Revistas, Bloque 5, Oficina 305.
Facultad Tecnológica
Universidad Distrital Francisco José de Caldas
Transversal 70 B N. 73 a 35 sur
Teléfono: 571 – 3239300 Extensión: 5003
Bogotá D.C., Colombia
Email:
tecnura.ud@udistrital.edu.co, tecnura@gmail.com
Página web:
https://revistas.udistrital.edu.co/ojs/index.php/Tecnura

Instructions for authors

https://revistas.udistrital.edu.co/index.php/Tecnura/about/submissions

CONTENT

Tecnura journal is an institutional publication of the Faculty of Technology from University Francisco José de Caldas. It is a scientific and technological publication with quarterly periodicity, which is published in January, April, July and October. The first issue appeared in the second semester of 1997 and up to now it has maintained its regularity.

The areas of interest of Tecnura journal are focused on all engineering fields such as electronics, telecommunications, electricity, systems, industrial, mechanics, cadastral, civil, environmental, among others. However, it is not restricted to those; it also has room for education and health issues, as long as they are related to engineering. The journal will only publish concerning scientific and technological research, reflection and revision. In consequence, during the initial editorial evaluation, short articles and case reports will be rejected.

Tecnura Journal is addressed for professors, researchers, students and professionals interested in permanent update of their knowledge and follow-up of scientific-technologic processes in the field of engineering. Tecnura Journal has as mission to disseminate results of research projects in the areas of engineering, through the publication of original and unpublished articles, conducted by academics and professionals accredited by public or private national or foreign institutions. Articles submitted to Tecnura journal must be unpublished works written in Spanish or English; nevertheless, preference will be given to articles that show innovative concepts of great interest, related to the objective and scope of the journal.

Tecnura is an academic publication indexed in the Regional Index Scielo Colombia (Colombia) and Redalyc (México); as well as of the following bibliographic databases: INSPEC of the Institution of Engineering and Technology (England), Fuente Académica Premier of EBSCO (United States), CABI (England), Index Copernicus (Poland), Informe Académico of Gale Cengage Learning (México), Periódica from the Universidad Nacional Autónoma de México (México), Oceanet (Spain) and Dialnet from the Universidad de la Rioja (Spain). It is also part of the following directories: Online Regional

Information System for Scientific journals from Latin America, Caribbean, Spain and Portugal Latindex (México), Bibliographic Index Actualidad Iberoamericana (Chile), e-Revistas (Spain) , DOAJ (Sweden) and Ulrich of Proquest (United States).

Tecnura is a journal arbitrated by a revision process among double blind peers. The schedule of the conformation of its scientific and editorial committee is subject to the publication of articles in internationally indexed journals by their members.

District University Francisco José de Caldas, its directors, the editor, the editorial and scientific committee are not responsible for the opinions and the criteria expressed in the content of the articles and they are published under the exclusive responsibility of the authors and do not necessarily reflect the ideas of the editorial committee.

In addition to the printed version, Tecnura journal also has a digital version available in its web page: http://revistas.udistrital.edu.co/ojs/index.php/Tecnura/index

TYPE OF ARTICLES ACCEPTED

According to the classification of the Scientific and Technological Publications National Index (Publindex-Colcienc Tecnura journal receives nominations of unpublished articles on the following topics:

- **Scientific and technological research articles:** document that presents, in a detailed manner, the original results of research projects. The generally used structure contains four main parts: introduction, methodology, results and conclusions.
- **Reflection articles:** document that presents research results from an analytic, interpretative or critic perspective from the author, dealing with a specific topic and adopting original sources.
- **Review article:** document that results from a research where the results of published or unpublished research on a science or technology field are analyzed, systematized and integrated, in order to state the advances and tendencies in development. It is characterized for presenting a careful bibliographical review of at least 50 references.

ARTICLE FORMAT

About the appropriate language and style for articles writing

- Authors must use simple sentence structures, avoiding those too long or complex.
- The vocabulary used must be basic and common. Technical language must be briefly explained; also, the meaning of the acronyms must be given the first time they appear in the text.

- The authors are responsible for their work to be conducted in a professional and ethic manner.

About the length of articles

The articles should not exceed 25 pages in letter size and double space, with symmetric margins of 3 cm. Only in the case of review articles, these 25 pages do not include references.

About the presentation format

Submitted articles must be unpublished works written in Spanish or English, and must be typed in Microsoft Word (2003 and beyond), complying with the following indications:

- *Times New Roman* letter, 12 point (except it is required for some sections).
- One column, double-spaced.
- All the margins 3 cm.
- Paragraphs should be justified without spaces between consecutives and without cutting words.
- Do not include page breaks or section finals.
- If you want to emphasize words or phrases from the text, do not use bold letters but italic.
- Decimals should be pointed with comma (,) and not with period (.).
- Thousands and millions should be pointed with a fine space.
- Avoid footnotes.
- Arabic nomenclature must be used only until the third level.

About the article structure

The papers must have the following structure and comply with the following requirements:

Composition of an article

All the articles submitted for evaluation and possible publication by the Tecnura Journal must have at least the following components:

- Title in Spanish and English.
- Information about the authors.
- Abstract in Spanish and English.
- Key words in Spanish and English.
- Introduction.

- Conclusions.
- Future work (optional).
- Acknowledgements (optional).
- Bibliographical references.

If the article is related to scientific and technological research must have, in addition to the above, the following components:

- Methodology.
- Results.
- Financing.

Title

The title of the article must be short or divided in title and subtitle, attractive for the potential reader and written in capital letters. It should appear centered between the margins, written in *Times New Roman* letter, in bold, font size 18. The title of the article has to be in Spanish and English separated by double space. Maximum 20 words.

Authors

After the title the complete name(s) of the author(s) must be written, with their basic biographical data: undergraduate degree, graduate degree, occupation or position, institutional affiliation (institution where they work), dependency, city, country and e-mail. The above information must be immediately below the author's name.

Abstract

The scope and purpose of the work must be established giving a clear and concise description of the methodology, results presented and the conclusions obtained. Maximum of 250 words.

Keywords

Between three and ten keywords must be chosen, written in English with *Times New Roman* letter in bold and italic.

Key words must be written in alphabetic order and must be as standard as possible, for which it is suggested the use of international databases accor- ding to the area of knowledge. For example, in the area of Electrics and Electronics it is suggested to use the IEEE thesaurus and World Bank thesaurus that can be accessed at the following web pages respectively:

http://www.ieee.org/documents/2009Taxonomy_v101.pdf
http://multites.net/mtsql/wb/site/default.asp

Abstract in Spanish

Translation to the Spanish language of the text that appears in the abstract, it must be correct and precise.

Keywords in Spanish

Translation to the English language of the keywords in Spanish, they must be correct and precise.

´ Keywords must be written in the order of the English version and must be as standard as possible, for which it is suggested the use of international databases according to the area of knowledge. For example, in the area of Electrics and Electronics it is suggested to use the UNESCO thesaurus that can be found at the following web pages:

http://databases.unesco.org/thessp

Introduction

The general idea of the work must be described, its context, backgrounds, state of the art of the topic, objectives and possible scope of the work.

Methodology

The writing of this part must allow any specialized professional in the topic to replicate the research.

Results

Explanation and interpretation of the findings. If necessary, a brief discussion focused on the interpretation of the results can be presented.

Conclusions

Implication of the results and their relation to the proposed objective.

Financing

Mention the associated research from which the article was derived and the entity that endorsed and financed the research.

Acknowledgments

They should preferably be brief and include the essential contributions for the development of the paper.

Equations

Equations must appear centered with respect to the main text. They must be referenced with consecutive numbers (written in parenthesis close to the right margin). Equations are cited in the main text employing the word equation, and followed by the number in parenthesis. Equations must be made in an appropriate equation editor and compatible with "InDesign" software, as for example the equation editor of Windows.

Tables

In the case of implementation of tables, it is recommended that these are not inserted as images, considering that in that format they cannot be modified. The title of each table must include the word table (in italic) followed by the corresponding consecutive number and a brief name of the table. The heading must be written in TNR letter, italic and font size 9.

Charts are not presented but tables and they should be automatically raised from the text processor. Tables should be named and referenced in the article, in strict order. Every table must have at the bottom the source from which it was taken, or to mention self-authorship if it is the case.

Figures

All the figures or pictures have to be sent in JPG or PNG format with a minimum resolution of 300 DPI, adapted to gray scale.

The footnote or name of each figure must include the word figure (in italic) followed by the corresponding consecutive number and a brief description of the content of the figure. The footnote of the figure must be written in Times New Roman letter, italic and font size 9. Figures must be named and referenced in the article, in strict order. Every figure must have at the bottom the source from which it was taken, or to mention self-author-ship if it is the case.

Symbols

The symbols of the constants, variables and functions in Latin or Greek letters –included in the equations- must be in italic; the mathematical symbols and the numbers do not go in italic. The symbols must be identified immediately after the equation. Units, dimensions and symbols of the international system must be used.

When using acronyms or abbreviations, the complete equivalence should be written first, followed by the corresponding acronym or abbreviation in parenthesis and from there it is only written the respective acronym or abbreviation.

Bibliographic references

The adopted reference citation style by Tecnura journal is APA sixth edition. The cites, bibliographic

references and infography are included in the last part of the article. The bibliographic references must be alphabetically ordered according to the author's first surname, without numbering.

There should only appear the cited references in the main body of the work, in tables or in figures. It means, in the list there should not appear other references although they have been consulted by the authors for the work preparation. We suggest using tools such as: Cites and bibliography from Microsoft Word (for APA sixth edition version 2013 or superior), Zotero, Mendeley, among others.

The call for a bibliographic reference is inserted in the text, at the pertinent point, under certain characteristics:

- If the sentence includes the author's surname, it should only be written the date into a parenthesis, for instance:
  Cuando Vasco (2012), analizó el problema de presentado en ....
- When the author is not included in the sentence, surname and date must be into a parenthesis.
  La investigación de materiales dio una visión en el área (Martínez, 2012).
- If the document or work has more than two authors, the first cite must include all the surnames. 1990. (Fernández Morales, Villa Krieg & Caro de Villa, 2008) ....
- In the following mentions, it must only be written the author's first surname, followed by "et al.". En cuanto al estudio de las aguas, Fernández Morales et al. (2008) encontraron que ...
- When the document or work has more than six authors, it must be used from the first mention "et al.".

Next it is described a series of examples of the more used references, according to the reference style adopted by Tecnura journal:

Periodical Publications:

Basic Form

Surnames, A. A., Surnames, B. B. & Surnames, C. C. (Date). Article's title. Title of the publication, volu- me (number), pp. xx-xx. doi: xx.xxxxxxx

Basic article

Guevara López, P., Valdez Martínez, J., Agudelo González, J., & Delgado Reyes, G. (2014). Aproximación numérica del modelo epidemiológico SI para la propagación de gusanos informáticos, simulación y análisis de su error. Revista Tecnura, 18(42), 12 -23. doi:http://dx.doi.org/10.14483/udistrital.jour.tecnura.2014.4.a01

Web article

Rodríguez Páez, S., Fajardo Jaimes, A., & Páez Rueda, C. (2014). Híbrido rat-race miniaturizado para la banda ISM 2,4 GHZ. Revista Tecnura, 18(42), 38-52. Recuperado de http://revistas.udistrital.edu.co/ojs/index.php/Tecnura/article/view/8059/9675

Books:

Basic Form

Surnames, A. A. (Year). Title. City: Editorial.

Surnames, A. A. (Year). Title. Recovered from http://www.xxxxxx.xxx

Surnames, A. A. (Year). Title. doi: xx.xxxxxxxx

Surnames, A. A. (Ed.). (Year). Title. City: Editorial.

Book with author

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For any additional information request, please send an e-mail to Tecnura journal tecnura@udistrital.edu.co or by mail to Cesar Augusto Garcia Ubaque, Director and Publisher of Tecnura Journal, to the following address:

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