Athenea

Revista en Ciencias de la Ingeniería

ISSN: 2737-6439
DOI: 10.47460/athenea
Volume 4, Issue 12
June 2023

2023

Published by:

AutanaBooks
Engineering & Services

ATHENEA JOURNAL

JOURNAL IN ENGINEERING SCIENCES

Electronic Journal Edited By AutanaBooks.

Quarterly Periodicity

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Exoskeletons reduce physical exertion on users, helping them perform physical tasks more efficiently and with less fatigue. On the other hand, exoskeletons also perform mechanical work by assisting users in performing tasks, such as lifting heavy loads or performing repetitive movements.

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Volume 4 // Issue 12 // June 2023
DOI:10.47460/athenea
ISSN: 2737-6439

Viewing the Journal:
https://athenea.autanabooks.com/index.php/revista

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JOURNAL IN ENGINEERING SCIENCES

ACADEMIC COMMITTEE

Athenea Journal
Volume 4 // Issue 12 // June 2023
DOI:10.47460/athenea/v4i11
ISSN: 2737-6439

Content

Editorial

Engineering is constantly evolving and challenging, and one field revolutionizing this discipline is Artificial Intelligence (AI). Developments in AI present engineering with a wide range of global and exciting challenges that require attention and reflection. These challenges span areas ranging from ethics and responsibility to safety and reliability and human-machine collaboration. In this sense, human-machine collaboration has become a relevant challenge. Effective AI integration involves designing systems that complement human skills rather than replace them.

The number 12 of the journal Athenea in engineering sciences, highlights the development of engineering for different scientific situations, such as the design of exoskeletons and the design of equipment from the virtues of extremophiles, without neglecting the applications that improve educational resources and the transcendence of education for engineering.

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Franyelit Suárez

ISSN-E: 2737-6419

Athenea Journal,
Vol. 4, Issue 12, (pp. 7-13)

https://doi.org/10.47460/athenea.v4i12.53

Application of data mining to understand some factors that influence student dropout

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Received (23/10/2022), Accepted (07/05/2023)

Abstract. - The research aims to identify applying data mining to identify the main factors that influence the dropout of university students in public universities in Latin America. A documentary analysis was carried out to contextualize the problem of student desertion, and relevant antecedents on the subject were presented. The study's main findings identified that socioeconomic problems, institutional conditions, and social and cultural environment situations are the main factors influencing student dropout in public universities in Latin America. Finally, it is possible to affirm that data mining is helpful for different engineering applications that contribute to the attention of social problems.

Keywords: Data mining, student dropout, engineering development.

Aplicación de la minería de datos para comprender algunos factores que influyen en la deserción estudiantil

Resumen: La investigación tiene como objetivo identificar aplicar la minería de datos para identificar los principales factores que influyen en la deserción de los estudiantes universitarios en universidades públicas de Latinoamérica. Se realizó un análisis documental para contextualizar el problema de la deserción estudiantil y se presentaron antecedentes relevantes en el tema. Entre los principales hallazgos del estudio, se identificó que los problemas socioeconómicos, las condiciones institucionales y las situaciones del entorno social y cultural, son los principales factores que influyen en la deserción estudiantil en universidades públicas de Latinoamérica. Finalmente es posible afirmar que la minería de datos es útil para diferentes aplicaciones de ingeniería que contribuyan a la atención de problemas sociales.

Palabras clave: Minería de datos, deserción estudiantil, desarrollo de ingeniería.

I. INTRODUCTION

Student dropout is a problem that affects many public universities worldwide. Universities often implement strategies to address this issue, but they must be more effective. Data mining has been increasingly used to identify the factors contributing to student dropout in public universities. This work analyzes the most common factors influencing student dropout in public universities using data mining techniques [1], and the strategies universities can implement to address this problem.

In this regard, academic performance is among the most influential factors in student dropout. Students with poor academic performance are more likely to leave the university. According to a study conducted by the National Autonomous University of Mexico (UNAM) [2], students with a cumulative weighted average (CWA) of less than 7.0 are 76% more likely to drop out compared to those with a CWA of 8.0 or higher. Additionally, students with poor academic performance in their core specialization courses are likelier to drop out [3]. Other authors found that students with a low CWA in their first semester of the study were likelier to drop out [4].

With these premises, it has been observed that institutional support is another influential factor in student dropout. Students who do not receive institutional support are more likely to leave the university. Another study [5] states that students not participating in tutoring programs have higher chances of dropping out. Students who feel disconnected from the university community are also prone to abandoning their university studies.

Furthermore, socioeconomic factors also play a role in student dropout. Students from low-income households or those who have to work while studying are more likely to drop out of university [6]. Other researchers [7] claim that students who have to work are exposed to dropping out due to the pressure of balancing work and studies. Students from low-income households are also in this situation as their families cannot cover the education expenses.

Other studies [8] suggest that students reporting higher levels of anxiety and depression are more likely to drop out of university. Student dropout in public universities is a complex and multifaceted problem that has been the subject of numerous studies worldwide. Data mining has been increasingly used to identify the factors contributing to student dropout in these institutions.

A literature review reveals several factors necessary for student dropout in public universities. One of these factors is academic performance [9]. For example, a study conducted by [10] in a public university in Spain found that students who received low grades and had a low cumulative weighted average (CWA) were more likely to drop out.

Therefore, data mining has been successfully used to analyze the factors influencing student dropout in different contexts and has provided valuable information for developing effective strategies to reduce the student dropout rate in public universities.

In recent years, data mining in the educational field has allowed the identification of patterns and trends that help better understand the factors influencing student dropout. Data mining is extracting valuable and relevant information from large datasets using statistical techniques and machine learning algorithms.

II. DEVELOPMENT

When engineering seeks to contribute to education for process improvement, technical elements are always linked to social aspects. In this sense, analyzing different software tools has been considered to develop an appropriate analysis of the factors influencing student dropout.

There are several programming packages suitable for data mining, such as:

Python: Python is one of the most widely used languages in the data mining community. It has a wide variety of libraries and specific tools for data analysis, such as pandas, NumPy, sci-kit-learn, and TensorFlow. In addition, python is known for its easy-to-read syntax and flexibility, making it ideal for beginners and experts.

R: R is another highly used language in data mining and statistical analysis. It is trendy in the academic community and offers various packages and libraries specializing in statistics and data analysis. In addition, R provides a plethora of advanced statistical functions and data visualization capabilities.

Both languages are powerful and widely used in the data mining community. However, for simple and accessible data analysis, Python can be an excellent choice due to its smoother learning curve and the abundance of online resources, tutorials, and examples available.

It is important to note that to carry out proper code that helps understand the causes of university dropout, it is necessary to delve deeply into the study topic. The causes of student dropout in Latin America are a complex issue developed by a diversity of researchers in various forms. In this regard, to study university dropout in Latin America, multiple factors that can influence this issue must be analyzed, including:

Socioeconomic factors: The economic situation of students and their families is crucial. Evaluating the impact of tuition costs, transportation, accommodation, and educational materials on the decision to drop out is necessary. It is also essential to analyze the influence of poverty, inequality, and lack of job opportunities for graduates.

Access and level of preparation: Barriers to access to higher education, such as lack of available spots, difficulties in the selection process, and inequities in the education system, should be investigated. Examining students' academic preparation level when entering university is relevant since a lack of prior knowledge can lead to difficulties and demotivation.

Academic support and guidance: Assessing educational support programs, such as tutoring, mentoring, or counseling services, is crucial. These resources can help students overcome academic challenges and provide guidance throughout their university journey.

Quality and relevance of education: Analyzing the quality of education provided in institutions is essential. Lack of academic quality, the relevance of study programs to the job market's needs, and a disconnect between theory and practice can affect student motivation and interest.

Socio-cultural context: Considering the socio-cultural context and family and community expectations about higher education is essential. Some students may need more time to drop out and work, especially in areas with limited access to well-paid jobs.

Psychosocial and emotional factors: Psychological and emotional aspects also influence university dropout. Lack of self-confidence, low self-esteem, stress, anxiety, or depression can lead students to abandon their studies.

Retention policies and programs: Examining policies and programs implemented by institutions and governments to prevent dropout is relevant. This includes the availability of scholarships, financial aid, student retention strategies, and actions to strengthen the link between higher education and the job market.

III. METHODOLOGY

To perform the analysis of student dropout factors in public universities using data mining techniques, a methodology consisting of several steps was employed:

1) Data collection: Data from students at a public university were gathered, including their academic performance, socioeconomic status, and participation in institutional support programs.

2) Data preparation: The data underwent cleaning and transformation to ensure suitability for analysis. Missing data were eliminated, and categorical variables were transformed into numerical ones.

3) Exploratory data analysis: Exploratory data analysis was conducted to identify patterns or relationships among variables. Data visualization techniques such as graphs and tables were used to summarize the data and visualize the relationships.

4) Data modeling: Data mining techniques, such as logistic regression and decision tree analysis, were applied to identify the most influential factors in student dropout. These models were used to predict the probability of students leaving the university based on personal and academic characteristics.

5) Interpretation of results: The results of the models were interpreted to identify the most influential factors in student dropout. These findings were used to develop strategies to reduce the university's dropout rate.

The software used for this work consisted of the elements described in Figure 1. R software was employed to determine the primary factors influencing dropout. Data inputs included student grades, class attendance, demographic data, contextual labor factors, family environment, and institutional characteristics.

It is important to note that the methodology and factors analyzed may vary depending on the specific context of each university and the research focus.

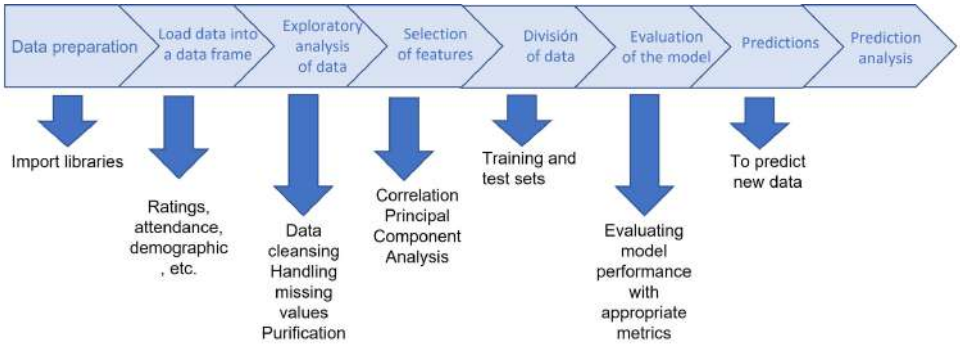

Fig. 1. Diagram of the development used in R.
Source: Own.

On the other hand, the model developed with logistic regression presents the characteristics described in Fig. 2. It is essential to highlight here that it was necessary to adjust the model since it did not seem stable, and a parameter adjustment was essential to achieve the model's stability.

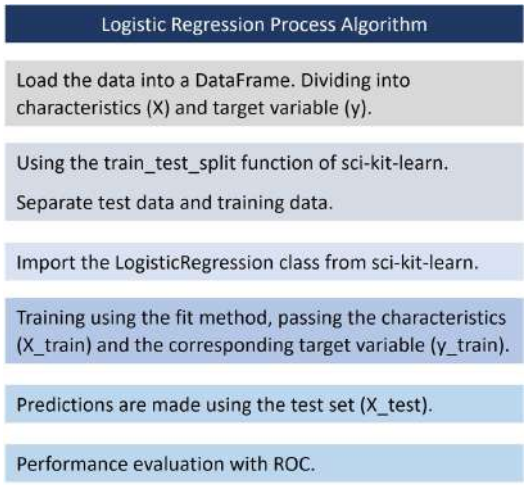

Fig. 2. Algorithm performed for logistic regression.
Source: Own.

IV. RESULTADOS

Data mining was applied to a dataset that included information on students from various public universities to analyze the factors contributing to student dropout in public universities. The results obtained revealed several factors that can contribute to student dropout in these institutions:

1) Academic performance was found to be a critical factor. Students with low academic performance are more likely to stay in their studies. Additionally, students who need help to meet the academic requirements of their study programs also have a higher likelihood of staying in.

2) The data mining results showed that financial difficulties are an essential factor. Students who need help paying their tuition fees or who have to work while studying are more likely to drop out.

3) Lack of motivation and disinterest in the academic program contributed to student dropout. Students who need a clear purpose for their studies or are not interested in their educational programs are likelier to drop out.

4) Personal problems were also identified as a significant factor in student dropout. Students facing personal issues such as mental health problems, family issues, among others, are more likely to drop out of their studies.

5) The choice of an academic program was a crucial factor. Students enrolling in educational programs that do not align with their interests or skills are likelier to drop out.

The literature review also revealed low percentages of individuals with completed studies in Latin American countries (Fig.3), primarily influenced by the economic and political factors in the region.

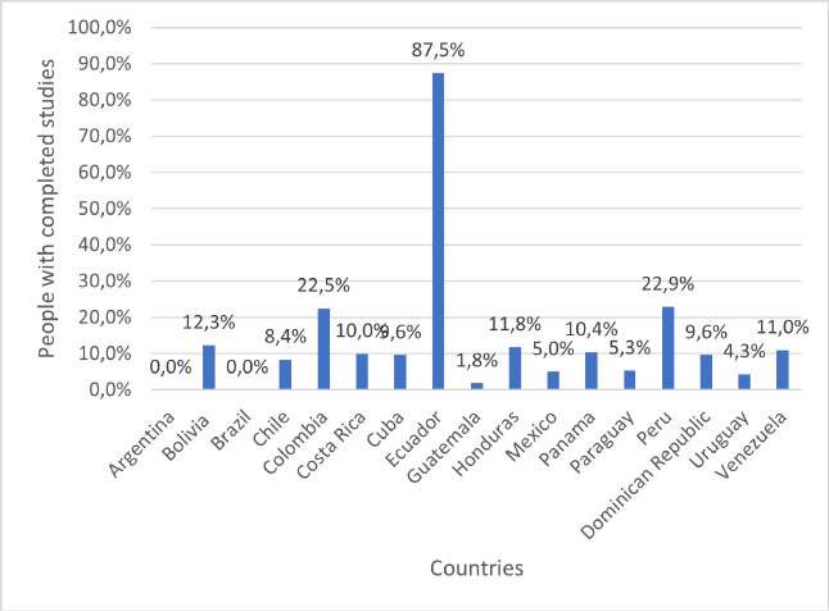

Fig. 3. Persons with completed studies in Latin America [11].

CONCLUSIONS

Student dropout is a major problem in public universities that affects not only the students but also the institution and society. Early identification of the factors that influence student dropout is fundamental to preventing its occurrence and ensuring students' academic success.

In this context, data mining has been used as a valuable tool to analyze large student data sets and to identify patterns and correlations in the data that can help predict student dropout. Various factors have been identified as influencing student attrition, including academic, socioeconomic, personal, and institutional factors.

Data mining has enabled universities to identify students at risk of dropping out and provide them with the necessary support to complete their studies. In addition, it has also enabled universities to improve their policies and programs to reduce student dropout.

In economic terms, poverty and inequality in Latin American countries make access to higher education difficult for many students. The high costs associated with tuition, study materials, transportation, and living expenses can become significant barriers for those from low-income families. This can lead some students to drop out of school due to a lack of financial resources to continue. In addition, the economic situation can affect the job availability and job prospects of university graduates. Suppose a country's economy is in recession or there is a shortage of job opportunities. In that case, some students may feel discouraged from continuing their university studies, as they do not see a guarantee of finding a stable or well-paid job upon completion.

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ISSN-E: 2737-6419

Athenea Journal,
Vol. 4, Issue 12, (pp. 14-23)

https://doi.org/10.47460/athenea.v4i12.54

Engineering prototype based on the study of extremophiles

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Received (01/11/2022), Accepted (11/05/2023)

Abstract. - This paper discusses engineering options for understanding how extremophile organisms might shed light on the possibilities of life on other planets. The study of extremophiles is responsible for the life that can exist in highly hostile environments on Earth, such as volcanoes, arid deserts, or domains with high salt concentrations. Engineering could be the essential tool to know unexpected life scenarios so that developments in this sense are proposed. The proposed prototype is generated from the analysis of extremophiles so that an engineering development suitable for adaptation to complex environments and valuable for the best human living conditions is possible. The main results show that a design with these characteristics presents more advantages than other technologies.

Keywords: Life, organisms, survival.

Prototipo de ingeniería basado en el estudio de extremófilos

Resumen: En este trabajo se analizan las opciones de ingeniería para comprender cómo los organismos extremófilos podrían arrojar luz sobre las posibilidades de vida en otros planetas. El estudio de extremófilos se encarga de examinar la vida que puede existir en entornos extremadamente hostiles en la Tierra, como volcanes, desiertos áridos o ambientes con altas concentraciones de sal. La ingeniería podría ser la herramienta clave para conocer escenarios de vida inesperados, de tal manera que se proponen desarrollos en este sentido. El prototipo propuesto se genera a partir del análisis de extremófilos, de manera que sea posible un desarrollo de ingeniería apto para la adaptación a ambientes difíciles y útil para las mejores de las condiciones de vida humana. Los principales resultados muestran que un diseño con estas características presenta ventajas importantes en comparación con otras tecnologías.

Palabras clave: Vida, organismos, supervivencia.

I. INTRODUCTION

Life on Earth has proven incredibly adaptable, finding ways to thrive in even the most inhospitable and hostile environments. From the deep ocean to arid deserts to active volcanoes, there is a surprising variety of organisms capable of surviving in extreme conditions. These organisms, known as extremophiles, have evolved unique mechanisms that allow them to withstand extreme temperatures, high pressures, intense radiation, and toxic levels of chemicals [1].

Extremophiles are true masters of adaptation, challenging our traditional notions about the limits of life. Some can survive in shallow temperatures, such as the polar regions, where intense cold seems incompatible with life. Others, instead, thrive in volcanic hot springs, where temperatures can exceed 100 degrees Celsius [2].

In addition to extreme temperatures, extremophiles have adapted to high-pressure conditions, such as the abyssal depths of the ocean, where the pressure reaches levels unimaginable to most organisms. These beings have also demonstrated a fantastic ability to survive in highly toxic environments, such as the saline waters of hypersaline lakes or acidic sources rich in heavy metals [3].

Understanding how extremophiles have evolved to survive in these harsh environments gives us valuable insights into the diversity of life on Earth. It may also have important implications in our search for extraterrestrial life. By studying extremophile adaptations and survival mechanisms, we can understand what life might be like on other planets or moons with similar conditions [4]. In this sense, extremophiles' existence shows life's fantastic ability to adapt and survive in environments that defy all expectations. These organisms not only expand the understanding of biodiversity on the planet itself but also invite reflection on the possibilities of life in seemingly inhospitable places in the vast universe.

The involvement of engineering in the study of extremophiles has been fundamental to understanding how these organisms survive in hostile environments. Engineers have developed specialized techniques and tools to collect samples of these organisms in their natural habitat, allowing for a more detailed analysis of their adaptations. In addition, they have applied bioengineering concepts to replicate extreme conditions in the laboratory and recreate the environments in which extremophiles live. These engineering approaches have provided valuable insights into these organisms' biological responses and survival mechanisms [5].

Engineering has also played a key role in developing technologies to study and analyze the DNA and proteins of extremophiles. By using genomic and proteomic sequencing techniques, engineers have managed to identify specific genes and proteins that play a crucial role in extremophile adaptations. These discoveries have allowed a better understanding of the molecular mechanisms underlying survival in hostile environments and laid the foundations for developing technological applications inspired by extremophile adaptations [6].

Another area in which engineering has contributed significantly is the application of extremophile adaptations in various fields, such as biotechnology and medicine. Extremophiles have been shown to possess enzymes and proteins with unique properties, capable of functioning in extreme conditions that would be harmful to conventional organisms. Engineers have taken advantage of these adaptations to develop more stable and efficient enzymes in industrial processes and explore medical applications, such as in the production of thermostable drugs and the search for therapies for diseases related to oxidative stress [7].

Engineering involvement in the study of extremophiles has been essential to advancing our understanding of these organisms and their adaptations. From sample collection in extreme environments to genomic and proteomic analysis, engineering has provided crucial tools and knowledge to unravel the secrets of life in extreme conditions. In addition, the application of extremophile adaptations in different fields has opened up new technological and medical possibilities, taking advantage of the unique ability of these organisms to survive in challenging environments. Likewise, engineering is projected as a tool to solve an infinity of social, industrial, and scientific problems.

II. DEVELOPMENT

An extreme environment is an environment that exhibits physical, chemical, or biological conditions that are considerably different or more extreme compared to the usual requirements that support life on Earth. These environments can be hostile, difficult to inhabit, and pose significant challenges to living organisms. Some examples of extreme environments include [8]:

High temperatures: Places with extremely high temperatures, such as volcanic lava flows or hot springs, where organisms must deal with intense heat.

Low temperatures: Polar regions, glaciers, or cold underground environments, where temperatures can drop below freezing, presenting challenges to survival.

High pressure: The deep ocean, where the hydrostatic pressure is exceptionally high, exceeds sea-level pressure.

Acidic or alkaline environments: Places with extremely low or high pH, such as acidic lakes generated by volcanic activity or alkaline waters.

Saline environments: In regions with high salt concentrations, such as saline lakes or salt flats, salinity is much higher than in typical aquatic ecosystems.

Radiation: Places with high radiation levels, such as areas near radioactive sources or environments exposed to cosmic radiation in space.

Nutrient scarcity: Environments with limited resources, such as deserts or arid regions, where water and nutrients are scarce.

Absence of light: Underground or deep environments in the ocean, where sunlight cannot penetrate, creating conditions of total darkness.

These extreme environments present unique challenges to life. Still, they are also home to an incredible diversity of extremophile organisms that have evolved specialized adaptations to survive those harsh conditions. Studying these organisms and their adaptations provides valuable information about the limits of life on Earth and the possibilities for life in other extreme environments, including planets and planets in the solar system.

In this sense, extremophiles have evolved to survive and thrive in extreme environments inhospitable to most living things. These organisms exhibit various adaptive characteristics that allow them to cope with extreme conditions, such as extremely high or low temperatures, high pressures, severe acidity, high salt concentrations, lack of oxygen, and intense radiation. Their adaptations include enzymes and proteins stable under extreme conditions, resistant cell membranes, DNA repair mechanisms, and specialized metabolism.

Extremophiles are classified into different categories depending on the extreme environment in which they can survive. Some examples are thermophiles, which thrive in high temperatures; psychrophiles, which are found in icy environments; halophiles, adapted to high concentrations of salt; acidophiles, which can survive in highly acidic environments; and alkalophilic, which are found in highly alkaline environments. In addition, some extremophiles can withstand extreme radiation, pressure, or dryness [9].

The life forms of extremophiles can vary widely. Some extremophiles are single-celled microorganisms, such as bacteria and archaea, that can inhabit extreme environments such as hot springs, saline lakes, or hydrothermal vents on the ocean floor. Other extremophiles are multicellular organisms, such as some fungi, lichens, and algae, that can adapt to extreme conditions in polar regions, deserts, or volcanic environments. Even extremophiles capable of surviving in harsh conditions in outer space have been discovered, raising the possibility of life on other planets or moons.

Extremophile research has important implications in various fields. Studying their adaptations can provide valuable information for understanding the evolution and diversity of life on Earth. In addition, extremophiles have proven to have practical applications in biotechnology, as their stable enzymes and proteins can be used in industrial and medical processes. It is also investigated whether extremophiles could provide clues about the possibility of life on other planets since their adaptations could be relevant for survival in extraterrestrial environments. [10] Finally, it is necessary to recognize that extremophiles have evolved unique adaptations to survive in extreme environments. Their classification is based on the types of harsh conditions they can tolerate. Extremophiles can be single-celled microorganisms or multicellular organisms, and their study has implications for understanding life on Earth, biotechnology, and the search for life on other planets.

Extremophiles are found in various parts of the planet, such as volcanic hot springs, polar regions, arid deserts, deep oceans, hypersaline environments, and highly acidic or alkaline environments. Some examples of extremophiles include:

Thermophilic: They are organisms that can survive and reproduce in very high temperatures, even above 100 degrees Celsius. They are found in hot springs and underwater hydrothermal vents.

Halophiles: They are organisms adapted to highly saline environments, such as salt lakes or saline. They can tolerate much higher salt concentrations than most life forms could support.

Acidophiles: These organisms can live and grow in highly acidic environments, such as abandoned mines or acidic lakes generated by volcanic activity.

Alkalophiles: These are organisms adapted to highly alkaline environments, such as water lakes or alkaline sources. They can survive in high pH conditions.

Piezophiles: These organisms can withstand high hydrostatic pressures, such as those in the deep ocean.

The study of extremophiles is of great scientific interest, as it allows us to understand the diversity of life on Earth and the biological adaptations that allow survival in extreme conditions. In addition, these organisms could provide clues about the possibilities of life on other planets or moons in the solar system that present similar environments.

A. Extremophiles and engineering

Engineering can play an essential role in studying extremophiles and their applications. Here are some ways engineering can contribute:

Instrumentation and sensor design: Engineering can contribute to the design and development of specialized instruments and sensors for detecting and sampling extremophiles in their natural environment. These devices can be used to collect data and samples in extreme habitats and facilitate the study of these organisms.

Culture and maintenance technologies: Engineering can contribute to developing technologies and systems that enable the cultivation and maintenance of extremophiles in controlled laboratory environments. This helps researchers study and better understand the biological adaptations of these organisms and how they survive in extreme conditions.

Applications in biotechnology and medicine: Extremophiles possess unique adaptations and special enzymes that allow them to survive in extreme environments. Engineering can take advantage of these features for applications in biotechnology and medicine. For example, extremophile enzymes can be used in industrial processes that require extreme conditions, such as chemical production or bioremediation of contaminants.

Engineering can contribute to the study of extremophiles through instrumentation design, culture technologies, applications in biotechnology and medicine, space research, and materials design. These contributions help to understand extremophiles better, their adaptations, and their potential applications in various fields.

B. Contributions of engineering in the study of extremophiles

Some contributions of engineering in the study of extremophiles are mentioned below:
Remote sampling instrumentation: Robotic systems and drones equipped with specialized instrumentation have been developed to take samples and measure in remote and hard-to-reach locations, such as polar regions, acidic lakes, or hydrothermal vents on the ocean floor. These advances allow detailed information to be obtained without exposing researchers to the dangers of these extreme environments.

DNA sequencing technologies: Engineering has contributed to developing high-throughput, low-cost DNA sequencing technologies. This has facilitated the study of extremophile genes and genomes, providing crucial information about their adaptations and survival mechanisms under extreme conditions.

Bioremediation: Engineering has used extremophiles to develop bioremediation technologies to clean and decontaminate environments contaminated by toxic compounds or industrial waste. Some extremophiles can tolerate and break down hazardous chemicals, offering sustainable and efficient solutions for environmental remediation.

Bioengineering and nanotechnology: Bioengineering and nanotechnology have combined to develop sensors and drug delivery systems inspired by extremophile adaptations. For example, scientists have designed heat- and radiation-resistant materials and nanomaterials for drug transport and controlled release under extreme conditions.

Applications in space exploration: Extremophile studies have influenced the design of equipment and technologies used in space exploration. For example, research into radiation-resistant bacteria has developed protective materials for satellites and spacesuits. In addition, extremophiles provide valuable information about the conditions in which life might exist on other planets or moons, guiding space mission planning, and the design of probes and rovers.

These examples show how engineering has contributed to studying extremophiles and life in extreme environments. Advances in engineering continue to expand our knowledge and practical applications in this fascinating field.

C.Statistics of the extremophiles

It is estimated that there are thousands of species of extremophiles on Earth, adapted to a wide range of extreme conditions. These include bacteria, archaea, fungi, algae, and other microorganisms. In addition, scientists have verified that life exists in hot springs, in hydrothermal vents on the ocean floor, where temperatures can exceed 350 degrees Celsius. Communities of extremophiles have been discovered that survive in these extreme conditions based on chemosynthesis.

Extremophiles have been found in highly radioactive environments, such as the pools of highly contaminated water at the Chornobyl nuclear plant. These organisms can tolerate levels of radiation that would be lethal to most life forms. Life has also been found in acidic environments, such as Dallol Acid Lake in Ethiopia; extremophiles have been found able to survive at extremely low pH and high concentrations of acidic minerals. In addition, it has been observed that these species have adapted to salinity and are found in saline environments such as salt lakes and salt flats. For example, Lake Retba in Senegal, known as Pink Lake, is home to extremophiles adapted to high salinity and extreme conditions.

These examples demonstrate extremophiles' ability to adapt and survive in extreme conditions, showing their importance in understanding the limits of life on Earth and their potential in scientific, industrial, and medical applications.

III. METHODOLOGY

The methodological process was composed of the phases described in Figure 1, where it can be seen that the six stages include an evaluation of the adaptations and their use for engineering development.

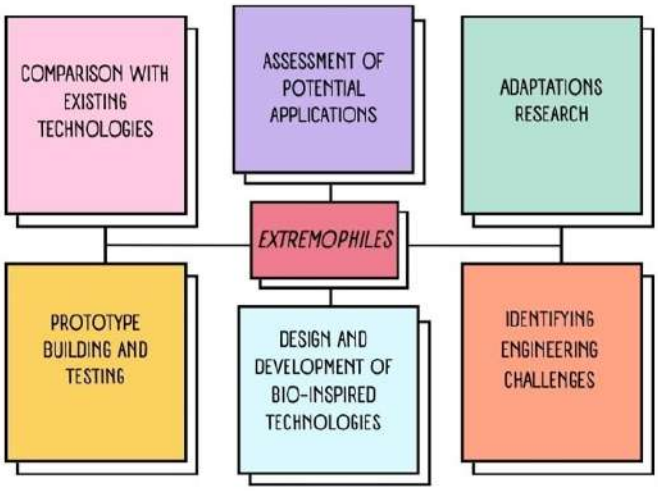

Fig. 1. Phases of implementation of the proposal.
Source: Authors.

Extremophile adaptations research: A comprehensive review of the scientific literature was conducted to identify critical adaptations of extremophiles to the extreme conditions in which they live. The structures, physiological mechanisms, and biochemical responses that allow them to survive were recognized.

Identification of engineering challenges: Different challenges or problems could be addressed by applying technologies adapted to extreme conditions, such as high temperatures, pressures, radiation, or aggressive chemical environments.

Design and development of bioinspired technologies: with the information collected, a proposal was designed for training in bioinspired technologies that can work in conditions similar to those of extremophiles. This training proposal for engineers aims to recognize the importance of survival in extreme environments and the need for innovation in the search for life on exoplanets.

Construction and testing of prototypes: The structure of a prototype water filtration system resistant to extreme conditions is proposed.

Comparison with existing technologies: The performance of the proposed bioinspired technology is compared with existing technologies in terms of efficiency, resistance, and adaptability to extreme conditions.

Evaluation of potential applications: The potential applications of the technology developed in fields such as medicine, industry, space exploration, or environmental protection are evaluated.

IV. RESULTS

The study of extremophiles allows us to know some characteristics for developing engineering systems that can be adaptive and facilitate scientific exploration in environments that are difficult for humans to access. Table 2 shows the features found in the detailed review carried out.

Tabla. 1. Characteristics of extremophiles.

Adaptation	Structure	Physiological Mechanism	Biochemical Response
Thermostability	Thermostable proteins	Stabilization of protein structures	Production of thermosetting proteins
Hyperthermophilic	Hyperthermophilic enzymes	Stability and activity at high temperatures	Adaptation to protein structure
Cryptobiosis	Spore formation	Suspension of metabolism and dehydration	Production of cell protectors
Dehydration	Protective proteins and lipids	Protection against dehydration	Accumulation of protective compounds
Halotolerance	Compatible solute carriers	Regulation of osmotic balance	Accumulation of compatible solutes
Radio tolerance	DNA repair enzymes	DNA damage repair	DNA protection and repair
Extreme pH	Proton pumps	Internal pH regulation	Internal pH control
Extreme pressure	Adaptations in membranes	Stability of cell structure	Modification of membrane lipids
Chemosynthetic metabolism	Enzymes and enzyme systems	Energy production from inorganic compounds	Adaptations in metabolic pathways

Fuente: Propia.

On the other hand, it was found that there are different challenges and problems in the development of technologies in engineering. Table 3 shows the main challenges encountered in the existing documentation.

Tabla. 2. Problems and challenges for the development of technologies.

Challenges/Problems	Description
Selection of suitable extremophiles	Identify and select the most relevant extremophiles adapted to the extreme conditions targeted.
Transfer of adaptations	Understand how to transfer extremophile adaptations to the design of human technologies efficiently.
Extreme condition replication	Design and create laboratory environments or test conditions that accurately simulate extreme natural conditions.
Strength and durability	Develop solid and durable materials and components that can withstand extreme conditions without degrading quickly.
Efficiency optimization	Improve the efficiency of bioinspired technologies to make them competitive with conventional methods.
Scalability and mass production	Adapt manufacturing processes to enable large-scale production of bio-inspired technologies.
Regeneration and maintenance	Design regeneration and maintenance mechanisms to extend the life and effectiveness of extremophile-based technologies.
Integrity and security	Ensure the integrity and safety of extremophile technologies, avoiding possible negative impacts on the environment and human health.
Economic cost	Develop bioinspired technologies that are economically viable compared to conventional alternatives.
Technology transfer	Overcome the challenges of effectively transferring bioinspired technology to industry and implementation in different contexts.

Fuente: Propia.

Based on these premises, the design of a technological engineering prototype is proposed, which includes the characteristics described and allows the generation of an engineering development suitable for use. In this sense, a water filtering system that applies to different scenarios is proposed.

This prototype would filter water in environments with high salinity concentrations, such as saltwater bodies or saline. It is inspired by the adaptations of extremophiles that can survive in highly saline environments. In addition, the operating mechanism is composed of a filtration system, which consists of a compact device that uses a combination of materials and bioinspired filtration techniques to remove salt and other impurities from water. It also uses a specialized membrane inspired by extremophile adaptations, which has a porous and selective structure that allows the passage of water while retaining salt ions and other impurities. This membrane mimics natural transformations, such as ion transport channels in extremophiles.

The filtered water is collected in a separate container, ready for use. It may include an additional sterilization or disinfection mechanism to ensure the water is free of harmful microorganisms. To maintain the efficiency of the filtration system in the long term, it is proposed to include a membrane regeneration mechanism. This mechanism removes accumulations of salt and other impurities from the membrane to restore its filtration capacity. This can be done using techniques such as washing with concentrated saline solutions or applying pulsed electrical currents to remove obstructions.

A system with these features is expected to have the following benefits:

- It can be used where salt or saline water is the only available source or where freshwater resources are limited.
- It can be applied in marine environments, desalination plants, expeditions in arid regions, or emergency situations where access to drinking water is needed.
- The prototype's bio-inspired technology offers an efficient, low-cost, and energy-efficient solution compared to conventional desalination methods.
- Table 4 compares with existing technologies, showing high efficiency and possible scalability, thus offering an opportunity for robust engineering development.

Tabla. 3. Problems and challenges for the development of technologies.

	Prototype filtration resistant to extreme conditions	Reverse osmosis	Evaporative distillation	Electrodialysis
Retention efficiency	Loud	Loud	Loud	Variable
Energy consumption	Low	High	High	Variable
Cost of operation	Low	High	Moderate	Variable
Maintenance requirements	Low	Moderate	Moderate	Variable
Installation area	Small	Big	Big	Moderate
Use of chemicals	Low	Moderate	Low	Moderate
Adaptability to extreme conditions	Loud	Casualty	Moderate	Moderate
Scalability	Possible	Possible	Possible	Possible
Applications	Marine environments, arid regions, emergencies	General	General	Specific

Fuente: Propia.

CONCLUSIONS

1. A water purification system based on the study of extremophiles can convert seawater into drinking water, allowing fresh water supply in coastal areas where water scarcity is an issue.

2. It can also be used in areas with little availability of fresh water since the system can filter water from wells or underground sources with high levels of salinity, providing a source of drinking water for the local population.

3. It is expected that, during expeditions in remote regions or camps in isolated areas, the system can provide drinking water by filtering local sources such as rivers, lakes, or springs with high concentrations of mineral salts.

4. In natural disasters or emergencies where the drinking water supply is affected, the proposed system can be used to purify contaminated or saline water, providing a safe water source for human consumption.

5. The water this system filters can be used in industrial and agricultural activities where quality water is required, such as crop irrigation or water supply for industrial processes.

6. Another functionality of the proposed system is for use in long-duration space missions, where access to fresh water is limited. The water filtration system is resistant to extreme conditions and can be used to recycle and reuse water, ensuring the supply of drinking water for astronauts.

A more in-depth study is necessary to define the possible adaptations that the proposed system could have so that its usefulness can be broad and diverse and can offer a resource as valuable as filtered water.

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ISSN-E: 2737-6419

Athenea Journal,
Vol. 4, Issue 12, (pp. 24-33)

https://doi.org/10.47460/athenea.v4i12.55

Engineering and innovation: a cleaner production proposal

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Received (01/11/2022), Accepted (11/05/2023)

Abstract. - This paper presents an engineering design that promotes cleaner production in silicone cutlery design. The idea seeks to motivate the consumer to maintain a healthy life by eating food made at home. For this, they propose cutlery of easy transfer and comfortable use for different tastes. The idea is driven by the search for new food proposals contributing to environmental conservation in eating implements. The main results show that the proposal is feasible and that waste consumption is considerably reduced with an appropriate cleaner production plan.

Keywords: Ecology, environmental protection, healthy eating.

Ingeniería e innovación: una propuesta de producción más limpia

Resumen: En este trabajo se presenta un diseño de ingeniería que promueve la producción más limpia en el diseño de cubiertos de silicón. La idea busca motivar al consumidor a mantener una vida saludable comiendo alimentos realizados en casa, para ello se proponen cubiertos de fácil traslado y cómodo uso para diferentes gustos. La idea se impulsa a la búsqueda de nuevas propuestas alimenticias que además aporten a la conservación ambiental en el proceso de elaboración de los implementos para comer. Los principales resultados muestran que la propuesta es factible y que se reduce considerablemente el consumo de desperdicios con un apropiado plan de producción más limpia.

Palabras clave: Ecología, protección ambiental, alimentación saludable.

I. INTRODUCTION

In everyday life, as in working life, we have sometimes sought to manufacture parts or products that are relatively the same. However, in many cases, obtaining a component that is the same or very similar to the one required is impossible, and sometimes the product manufactured with the necessary material and shape is unknown or cannot be found. Therefore, cloning or replicating the product or part is the most feasible. Within the text Silicone Mold Making [1], the exact repetition of a piece we call replication or cloning. The materials used to make it are varied (plaster, resins, soft metals); however, the image is based on two primary objects:

1.- The model or piece to replicate 2.- The mold that will serve to clone the model.

Silicone molds are tools used to create shapes and repetitive and creative designs that are used for different areas since silicone molds can be used with other materials or products such as resin, clay, soaps, bricks, candles, plates, or cutlery holders to take them anywhere. This last one is beneficial for the environment because in the food industry or restaurants, much plastic cutlery is used when it is sent by delivery or the order is sent to take away, according to the newspaper El Español [2] the *North Sea Foundation*, in the last 30 years of cleaning beaches around the world, The Ocean Conservancy has recorded the collection of more than 14 million disposable plastic cutlery, it should be noted that these take about 400 years to decompose.

The problem that arises worldwide is huge since plastic cutlery is a product that pollutes the environment; Marine life is one of the most affected since many animals swallow this type of waste that, relatively the use we give them a few hours, and proceeds to discard them. However, the solution can be straightforward. In the newspaper El Español in the case of eating out, we can bring our metal cutlery. Some companies develop small pocket cases that make it easy to transport essential eating tools on an excursion or in the workplace [3].

Therefore, using silicone molds to transport cutlery generates positive impacts, first on the environment since everyone would carry their metal forks in their case, and the use of plastics would be eliminated. These molds are durable, meaning their useful life will be extended. Restaurants or food companies would save costs and improve their image since many people are concerned about the environment. In addition, using silicone brings notable advantages in molds since, according to the Delicista Blog, these molds have the particularity that they are flexible, versatile, easy to clean, non-stick, resist very high temperatures (240ºC), and very low (-40C), soft but firm and affordable [3].

Similarly, within Latin America, many people buy food instead of taking their food, which causes the more they believe in restaurants or ask for takeaway food, the use of this plastic cutlery will continue to increase, according to the Quito newspaper Últimas Noticias. However, most Latinos prefer homemade food; 41% eat out when they can prepare food at home. This is a large number since most of these places send food in plastics, just as the cutlery they use is made of this same type of material. Also, another of the suggestions proposed by this newspaper is that food is taken from home, which would help reduce costs for people, and silicone molds are perfect for carrying food or cutlery anywhere, work, school, universities, etc [4].

II. DEVELOPMENT

Wacker Chemie AG is a German company that is one of the leading manufacturers of silicones. Among the products they make are silicone fluids, silicone resin, sealants, etc. The company is committed to sustainability and is climate-friendly and efficient with the use of resources. Within its website, it can be seen that the company also cares about human rights and social responsibility and that it has undoubtedly applied cleaner production plans within its production and its logistics area. Within its production, you use the waste gas, water, solids, and heat to start the production of other products [5].

Lékué is a Spanish company that manufactures functional products for cooking and home, such as silicone molds for baking and cooking, silicone steamers, cases, and containers for conservation. The company carries out its production under ethics and responsibility aligning with the UN SDGs that all operations and decisions contribute to preserving the environment, customer satisfaction, and motivating a new lifestyle. Lékué promotes the reduction of waste in the home since it produces reusable and durable products. The material has a long useful life. In addition, its manufacturing processes use technologies and practices that minimize energy consumption and reduce carbon emissions. The company is ISO 14001 certified for environmental management [6].

Lunette is a Finnish company that manufactures soft, flexible medical-grade silicone menstrual cups. The silicone used is hypoallergenic, non-porous, and free of harmful chemicals. The company offers products that are tailored to individual customer needs. This company strongly focuses on sustainability, and its effect is made from a durable and reusable material, which means it avoids waste. Lunette has suppliers and manufacturers who share ethical values, so recyclable and biodegradable materials are used within its packaging to minimize the environmental impact. The idea of this company in creating this product is to significantly reduce the waste generated by disposable menstrual hygiene products [7].

Due to the background mentioned above, currently, single-use products represent a problem to be solved since they form a large part of the pollution of our planet because they have doubled their production in the last two decades. The production of plastic causes the accumulation of waste, pollution of the sea, impact on wildlife, etc. The cutlery holder seeks to reduce the use of plastic cutlery and provide more comfort to customers. The product is manufactured from silicones, so the activities within silicone products will be presented below [8].

Manufacturing food-grade silicone involves using a unique formulation that meets safety standards. Food-grade silicone is manufactured from high-quality, high-purity silicone polymers and other ingredients. Silicone products' general extraction and manufacturing process is detailed below (Fig. 1).

Polymer production (raw material)

1. Obtaining monomers, chemical precursors, additives, and other raw materials.
2. Polymerization.
3. The processing depends on the characteristics of the desired end product.
4. Add additives.
5. Finishing and post-treatment.

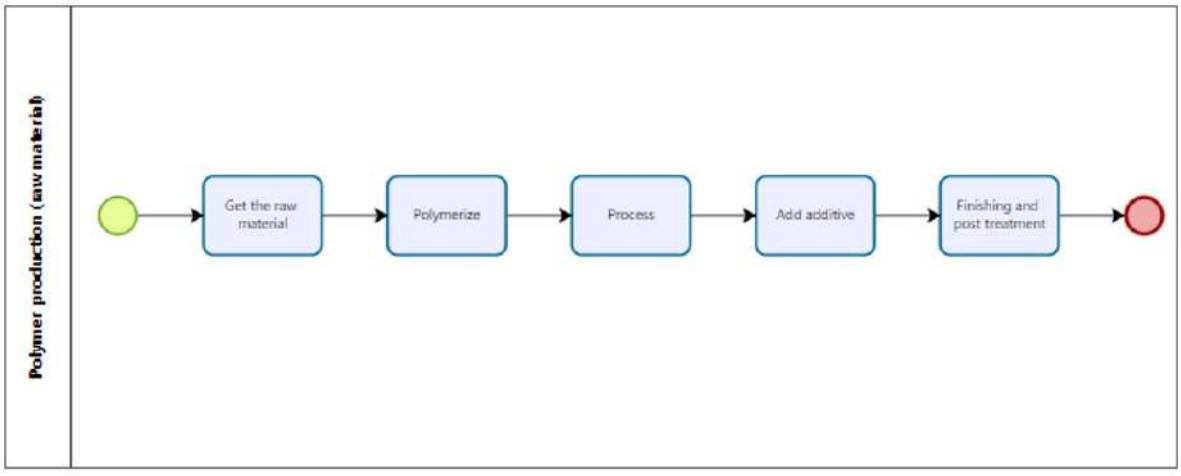

Fig. 1. Polymer production process.
Source: Own.

Within the extraction stage for the manufacture of the cutlery holder, some pollution can be generated, such as atmospheric emissions of volatile organic compounds (VOCs), wastewater containing chemical substances, solid waste, and the use of toxic chemicals.

Polymer-based silicone production

1. Selection of polymers based on quality standards.
2. Mix polymers with catalysts and additives based on the established formula.
3. Mixing and kneading to ensure components are evenly distributed.
4. The mixture undergoes a curing process, which may involve the use of heat or exposure to moisture.
5. Inspection and quality testing.

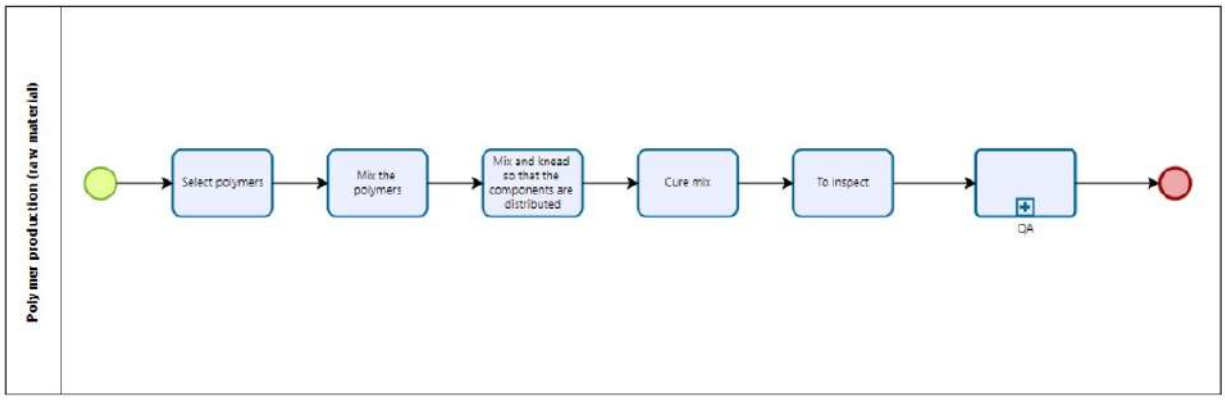

Fig. 2. Production of polymer-based silicones.
Source: Authors.

Within the production of silicones, there are potential pollution risks such as air emissions, chemical residues, and the use of hazardous chemicals.

B. Production of cutlery

Many people today decide to take food because it saves money, there is greater ease and control over the ingredients and portions consumed, and more options that eliminate the monotony when eating out. However, it is necessary to have all the elements such as napkins, cutlery, and condiments to be able food as if we were at home.

The proposal consists of a cutlery holder made of silicone that can adapt to any form of container, providing comfort, organization, and space-saving.

The elements that make up the product are the following:

1. Rectangular container with rounded edges made of silicone.
2. Adjustable snaps on the top, bottom, and sides.
3. Adjustable silicone strap.

Figures 3 and 4 show the proposed design, considering it is expected to be adaptable.

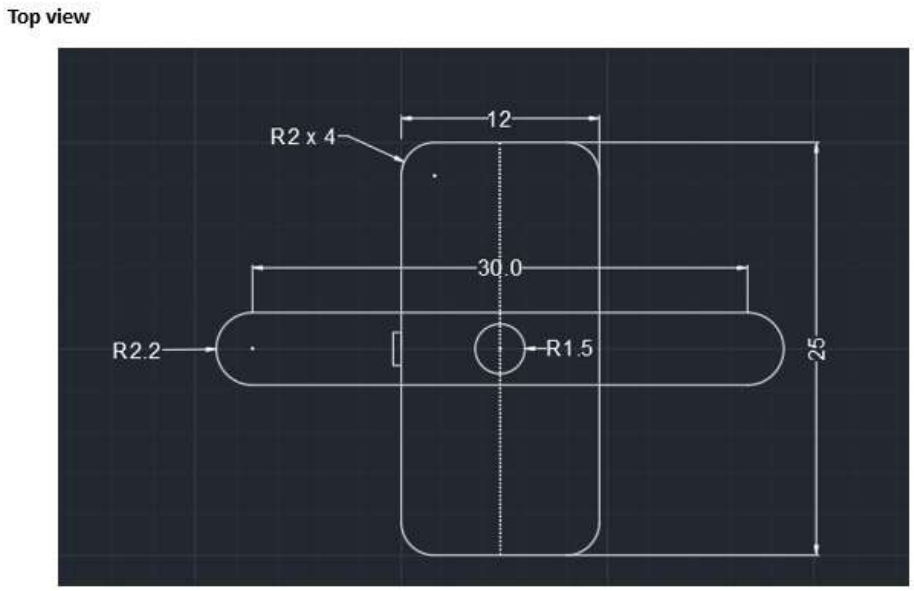

Fig. 3. Top view .
Source: Authors.

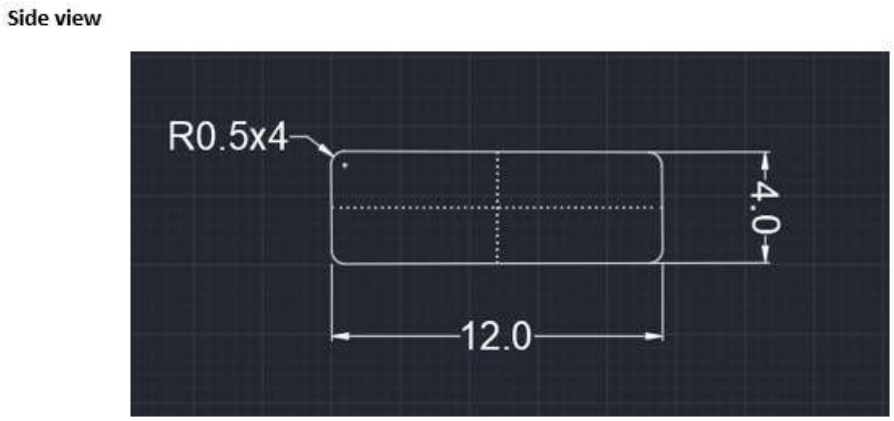

Fig. 4. Side view
Source: Authors.

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III. METHODOLOGY

Within the process of production of silicones from polymers, the stage that generates more pollution corresponds to the mixture of polymers with catalysts and additives based on the established formula; this is because the catalysts and additives that are added to the polymers contain chemical substances that impact the environment. To better understand what would be happening at this stage, we must know the functions of catalysts and additives. Catalysts are substances added in small quantities within the process, allowing silicones to harden and acquire properties; some catalysts can be platinum, tin, and titanium. Additives are substances such as plasticizers, thermal stabilizers, pigments, lubricants, and coupling agents that are added to silicones to improve or modify the characteristics of the final product.

Depending on the process, different catalysts and additives intervene. Unfortunately, some of these contain chemical substances that, when improperly treated, generate pollution, such as emissions of volatile compounds that contribute to smog formation, generate waste that does not degrade quickly in the environment, and, finally, can generate liquid effluents that can affect water and soil. This is why companies must implement sustainable and responsible production practices to minimize and control the environmental impact during this stage of the silicone production process.

Next, the flow of materials in this stage will be presented to make the corresponding P+L.

Material flow:

1. Enter polymers (granules, pellets, liquids).
2. Catalysts enter (liquid or powder).
3. Additives (liquid or powder) enter.
4. Enter water.
5. A mixing process occurs where the components are agitated to ensure even distribution.
6. A kneading process occurs where it is mixed more intensively and extensively to ensure the uniform distribution of the components.
7. A mixture of polymers, additives, and catalysts comes out.

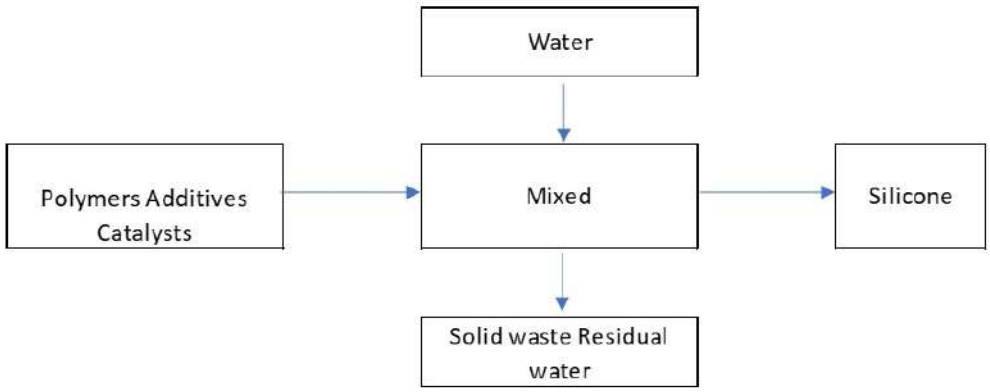


Fig. 5. Critical Process Material Flow Diagram
Source: Own.

Flow balance

To create the cleanest production plan, the flow balance was made based on the most critical operation corresponding to the polymer mixture (Table 1).

Table 1. Analysis of flow in critical operation.

Units	unit weight	unit	silicone to use	unit
500000	0,05	kg	25000	kg
use of raw materials for the production of 50,000 units				
polymer	60%	15000,0	kg	-
Water	30%	7500	7,5	m^3
additive to	3%	625,0	kg	-
additive B	3%	625,0	kg	-
catalyst A	3%	625,0	kg	-
Catalyst B	3%	625,0	kg	-

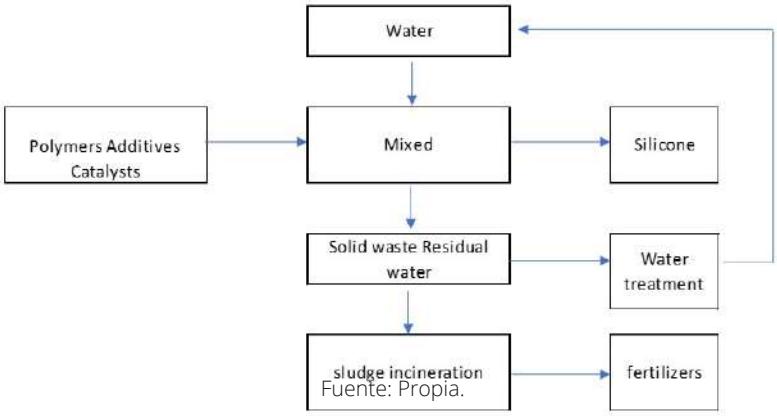
Table 2 shows the elements considered in the process input, considering the quantity and units of work.

Table 2. Process input materials.

Entrance

No.	Material	amount	Unit	C specific	full C	% Final product
1	polymer	15000	kg	$ 18,00	$270.00	59%
2	Water	8	m^3	$ 0.72	$ 5.4	17%
3	additive to	625	kg	$ 25,00	$390.63	1%
4	additive B	625	kg	$1.04	$26	1%
5	catalyst A	625	kg	$ 11,00	$6.88	1%
6	catalyst B	625	kg	$ 22,00	$13.75	1%

Flow balance To create the cleanest production plan, the flow balance was made based on the most critical operation corresponding to the polymer mixture (Table 1).



Fuente: Propia.

Fig. 6. Critical Process Material Flow Diagram
Source: Own.

With the addition of the water treatment plant and sludge incineration furnace, the following associated flow balance is obtained when the cleaner production plan has already been implemented.

IV. RESULTS

Table 3 shows the waste before the cleaner production plan. Again, it can be seen that there is significant waste in the water used in the process.

Table. 3. Problems and challenges for the development of technologies.

No.	Material	amount	Unit	C specific	full C	Total income (%)
2	Water	1	m^3	$ 0.72	$ 0.72	**13,3%**
3	polymer	200	kg	$ 18,00	$ 3,600	1,3%
4	additives	50	kg	$ 25,00	$ 12,50	4,0%
5	Catalyst	60	kg	$ 22,00	$4	4,8%

Table 4 shows the corresponding data once the cleaner production plan has been applied, and a significant change in water waste can be noted, which has been reduced by up to 6.7%. This value differs from the previous one by 51.53%, which indicates a considerable reduction with the cleaner production plan.

Table. 4. Waste after the cleaner production plan.

No.	Material	amount	Unit	C specific	full C	Total income (%)
2	Water	0,50	m^3	$ 0.72	$ 0.36	**6,7%**
3	polymer	200	kg	$ 18,00	$ 3,600	1,3%
4	additives	50	kg	$ 25,00	$ 12,50	4%
5	Catalyst	60	kg	$ 22,00	$4	5%

Additionally, the incineration of sludge with pollutants such as additives, catalysts, and polymers generates solid waste that acts as fertilizing agents suitable for agricultural use. In this way, the opportunity to generate income from selling these fertilizers to different companies is opened.

Figure 7 shows the relationship before and after applying the cleaner production plan, and the significant change in water waste can be noted.

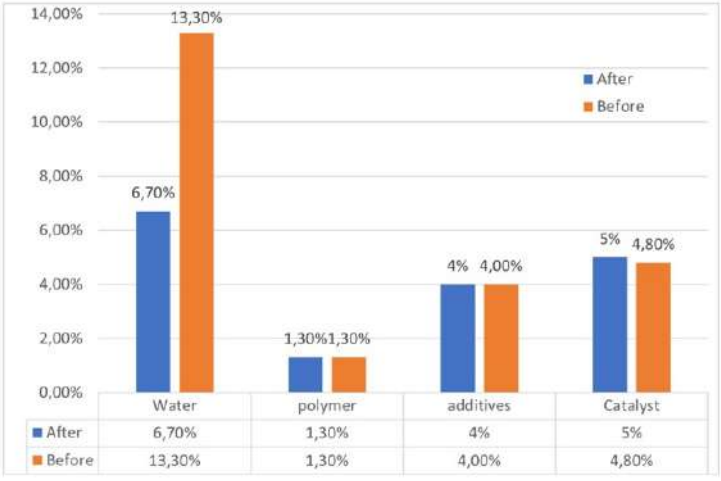


Fig. 7. Relationship before and after applying the cleanest production plan.
Source: Authors.

A. Economic analysis of investment

The equipment and implements necessary for implementing the cleaner production plan are presented below. Table 5 shows the most significant costs of the investment.

Table. 5. Investment of plant and furnace.

Investment in treatment plant and furnace	
investment	$ -500,000
interest	15%
Periods	5

When analyzing the net present value of the investment with a loan to the bank with an interest rate of 15% over a period of 5 years, a matter of one million two hundred and thirty-nine thousand one hundred and eighty-five dollars is obtained with an internal rate of return of 34% which infers that the investment means a viable project in which the company will get economic benefits in the reduction of the cost of production and sale of a new product obtained from waste and above all will reduce the environmental impact of its operations.

CONCLUSIONS

The analysis of the budget and the losses that occur during our production allows us to understand if there is viability to apply a cleaner production plan, so we can say that within our organization, a more pristine production plan can be used to reduce the waste of water and solid waste by implementing strategies that reflect the environmental commitment that is had in the production of our product.

Thanks to the detailed analysis that was carried out, it was possible to identify areas for improvement, which facilitates us to have better financial planning, greater control, informed decision-making, and effective communication, in addition to which it should be noted that the profitability and efficiency of our production process are improved.

The study carried out in this work gives us an understanding of the importance of understanding the processes and bonds of our company since, thanks to this. We can have comprehensive control concerning the risks that may arise in the company. It is essential to recognize that implementing a P + L allows us to grow the company, and that is maintained over time. It also positions us financially.

Being a sustainable company and applying a cleaner production plan opens the doors to new markets and customers. Furthermore, since it is currently valued that businesses are committed to sustainability, the realization of a project is innovative since it puts the company in a position to seek improvements and strategies.

By reducing water waste by 50% in our process, we contribute to the environment, which shows the concern that all companies must have for wanting to make a difference and support the fulfillment of objectives necessary to preserve our planet.

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ISSN-E: 2737-6419

Athenea Journal,
Vol. 4, Issue 12, (pp. 34-42)

https://doi.org/10.47460/athenea.v4i12.56

Advances of Artificial Intelligence in Aeronautics

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Received (01/11/2022), Accepted (11/05/2023)

Abstract. - The use of artificial intelligence (AI) in recent years has allowed the development of a large number of applications in practically all areas of human knowledge. However, the application is relatively new in aeronautics, and products are already optimizing the skills and capabilities of the personnel who command it. This paper reviews the scientific literature on the advantages, disadvantages, and aspects to consider regarding the application of AI techniques in aeronautical processes ranging from construction, navigation, and security against attacks on communications and climate changes that may affect the navigation system. AI developments provide new advantages and challenges for navigation every day. On the one hand, these techniques support flight independence until achieving absolute autonomy. Still, on the other hand, they also incorporate specific vulnerabilities and concerns about the increased use of computer and digital communication media that are prone to attacks by malicious individuals or organizations**.**

Keywords: Aeronautics, Artificial intelligence, machine learning, autonomous navigation.

Avances de la inteligencia artificial en la aeronáutica

Resumen: El uso de la inteligencia artificial (IA) en los últimos años ha permitido el desarrollo de una gran cantidad de aplicaciones en prácticamente todos los ámbitos del conocimiento humano. En la aeronáutica la aplicación es relativamente nueva y ya existen desarrollos que optimizan las destrezas y capacidades del personal que lo comanda. En este trabajo se presenta una revisión en literatura científica de las ventajas, desventajas y aspectos a considerar en torno a la aplicación de técnicas de IA en procesos de la aeronáutica que van desde la construcción, navegación y seguridad ante ataques en comunicaciones y cambios climáticos que pueden afectar al sistema de navegación. Los desarrollos en IA cada día aportan nuevas ventajas y desafíos para la navegación, por una parte, estas técnicas apoyan la independencia del vuelo hasta lograr la autonomía absoluta, así como también, incorporan ciertas vulnerabilidades y preocupaciones en torno a un mayor uso de medios informáticos y comunicaciones digitales que son propensas a ataques por parte de personas u organizaciones malintencionadas.

Palabras clave: Aeronáutica, inteligencia artificial, aprendizaje automático, navegación autónoma.

I. INTRODUCTION

Artificial intelligence has been incorporated into various human activities, also used in the aeronautical and aerospace industry, mainly to improve the efficiency and safety of flight operations. Its use in automation through flight management systems and autopilot has yielded excellent results. Despite the implementations of automatization, the effectiveness and safety of a flight also depend on human decision-making, aspects that remain crucial to ensure flight safety and whose appearance has yet to be replaced.

The aerospace industry has employed artificial intelligence despite uncertainties about the confidence that AI will provide when faced with critical situations, which are currently the responsibility of aviation experts. Guidelines, recommendations, and guidance have been proposed in the Research Manual on Applications of Artificial Intelligence in Aviation and Aerospace; In this work, the applications of AI in aviation and aerospace are addressed. The adoption of AI in this sector is a growing trend and focuses mainly on reducing human error and improving its efficiency[1].

According to Figure 1, artificial intelligence in aviation has been employed in air combat, the aeronautical industry, cognitive systems, aircraft maintenance repair, data analysis, defect detection, and deep learning in defect detection[2].

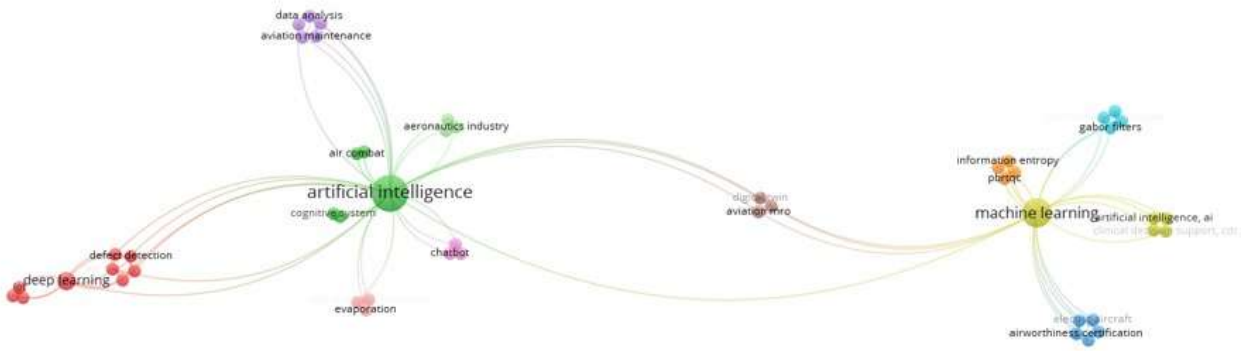

Fig. 1. A bibliometric review of the terms "Aeronautical Artificial Intelligence" in the SCOPUS Base (36 articles) graphed with VOSviewer®.

AI technology also supports the detection and resolution of onboard problems during flight, reducing the risk of falls and accidents by influencing the predictive stability behavior of aircraft. In addition, implementing advanced monitoring and tracking systems, such as predictive maintenance, allows airlines to identify and fix logistical issues before they cause flight disruptions. As a result, technology has been essential to ensure a better experience for the crew and in the operation of the aircraft.

Information collected on an aircraft is stored and used in air accident cases to generate reports and obtain evidence. The analysis of data and knowledge of the flights are already carried out efficiently with artificial intelligence applications, which are capable of performing very complex studies that involve all the electronic data of the entire aircraft allowing to provide a better result in the determination of evidence in accidents or causes of accidents[3].

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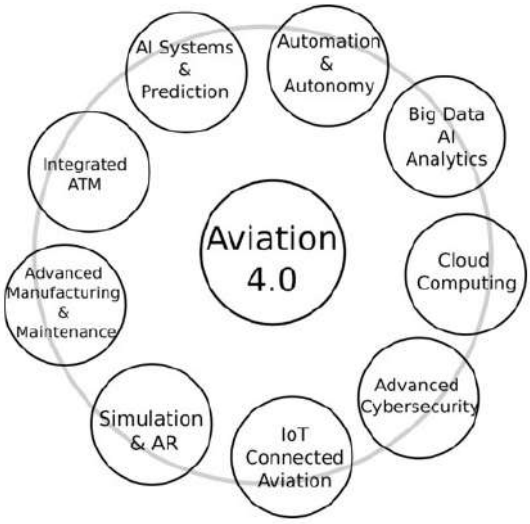

Fig. 2. Technological aspects addressed by Industry 4.0 in aviation.

This document describes applications that use AI and corresponds to the field of the aeronautical industry in the development section. Then, in the Methodology section, it is detailed how the reference information was obtained. Then, in the Results section, an analysis of the findings and trends in the use of AI in the field of aeronautics is presented; finally, the conclusions are offered.

II. DEVELOPMENT

This section describes some current applications implemented in the aviation industry according to an overview of the advances and applications that use AI to solve problems in aviation and its previous manufacturing processes. The information provided in this section allows researchers and professionals to know the state and influence of AI in aircraft navigation, control, manufacturing processes, management, and maintenance systems.

From the review of scientific literature, it was evident that the most relevant topics in which AI is used are machine learning and neural networks. The use of AI allows for improving the efficiency of the tasks. In addition, the functions and applications are also evolving, such as new projects under development, such as the implementation of autonomous air taxis and air transport of large and small objects.

Artificial intelligence has had a significant impact on the aviation industry. It has made it possible to improve flight safety by detecting potential problems and providing proactive solutions for securing them, as well as increasing operational efficiency by optimizing routes and reducing fuel consumption in the face of factors such as unfavorable weather conditions or others[7].

Flight safety has been improved with AI, enabling more accurate and faster real-time inspections of aircraft and equipment and detecting anomalous patterns in maintenance data. AI allows for optimizing air traffic management, flight planning, and fleet management, ensuring more efficient and safe air travel [6]. The aviation industry faces challenges of unscheduled maintenance, repair, and overhaul (MRO) costs. It is turning to advanced technologies such as artificial intelligence to improve efficiency and reduce costs by providing predictive analytics to identify problems before they occur, reducing unscheduled repairs and thus revolutionizing multiple aviation industry processes[6].

Tabla 1. Influence of AI on multiple aspects of the field and development of aeronautics.

Topic	Description
Efficiency optimization	AI is used to optimize efficiency in air traffic, route planning, and fuel management. AI algorithms can process large amounts of data and help air traffic controllers make more informed decisions. In addition, AI can help reduce airport waiting time and improve flight punctuality.
Improved security	AI is used in predictive aircraft maintenance, which means sensors on the plane can detect potential problems before they occur and alert the maintenance team so they can take preventative action. It also improves object detection on the track, reducing the risk of collisions and other accidents.
Development of autonomous aircraft	AI is being used to develop autonomous aircraft flying without a human pilot. These aircraft can be used for military, search and rescue missions, and commercial flights. In addition, autonomous aircraft can be safer and more efficient than crewed aircraft.
Advanced analytics capabilities	AI enables aeronautics data analysts to process large amounts of data and extract valuable insights. For example, machine learning algorithms can detect patterns in data that humans may miss and can help engineers design better aircraft and navigation systems.
Pilot training	AI is being used to develop advanced flight simulators that can help train pilots in different flight situations, from takeoff and landing to extreme weather conditions. Flight simulators can be a valuable tool for improving pilot safety and training.
Maintenance and repair management	AI is also used to optimize aircraft maintenance and repair management, as machine learning algorithms can analyze large amounts of maintenance and repair data to identify patterns and trends. This can help maintenance teams make more informed decisions and repair more efficiently.
Quality control and testing	AI is being used to improve quality control and aircraft testing. For example, machine learning algorithms can analyze large amounts of flight and component test data to detect problems and predict potential failures. This can help aircraft manufacturers improve the quality of their products and reduce warranty costs.
Aircraft design and simulation	AI is used in aircraft design and simulation to improve efficiency and reduce costs. Machine learning algorithms can analyze simulation data to identify the most efficient and secure designs. In addition, AI can help engineers design components.

The table above highlights eight aspects artificial intelligence has dramatically impacted aeronautics. Most of these aspects focus on improving efficiency, safety, and quality in the aviation industry. One of the highlights is optimizing efficiency in air traffic management, route planning, and fuel management. Artificial intelligence has enabled air traffic controllers to make more informed decisions and has helped reduce airport waiting time and improve flight punctuality. Security has also been an important area where artificial intelligence has significantly impacted aeronautics. AI-based predictive aircraft maintenance technology can detect potential problems before they occur, reducing the risk of accidents. In addition, the detection of objects on the track has been improved with AI, reducing the risk of collisions and other accidents. The development of autonomous aircraft has also been possible thanks to artificial intelligence, which has led to greater efficiency and safety in the aviation industry. In addition, AI has been used in advanced data analysis, pilot training, maintenance and repair management, quality control and testing, and aircraft design and simulation.

AI is used in various applications, from optimizing flight planning to improving safety and efficiency in air traffic management. AI assists managers (airline/airport managers, air traffic management) in a wide range of air traffic and aviation system applications (pilots, air traffic controllers, airport operators, flow controllers), also faces new tasks, energy transition, integration of new air traffic components and system difficulties in the face of traffic disturbances [8]. For example, optimizing flight planning using AI enables airlines to improve aircraft utilization and minimize delays. In addition, AI can also aid in air traffic management, where it is used to improve the safety and efficiency of flight management by analyzing data in real time and providing helpful information for air traffic controllers[9] [1].

AI is also being used to improve security at airports, for example, to identify suspicious objects by analyzing images obtained from surveillance video cameras and scanning systems. In addition to military pilots, the safety of the airspace system also depends on technology and equipment used in the aerospace industry, including radars, communications systems, and navigation and good coordination among employees of the air traffic control system. Furthermore, the implementation of advanced technologies such as satellite air traffic control (SATCA) and flight information systems (FIS) help improve the efficiency of the air traffic control system by providing excellent safety for passengers and flight teams[10].

Education and training of ATCS employees are essential to ensure the safety of the airspace system. Continuous training in the latest techniques and technologies is critical to keep employees up-to-date and able to respond to emerging situations. Artificial intelligence has great potential to improve air traffic management. AI can help improve efficiency in air traffic, increase infrastructure capacity, reduce delays, and improve safety. Some AI applications in Air Traffic Management (ATM) include route optimization, congestion forecasting, and runway capacity improvement[11].

Air traffic management will become increasingly complex due to the growth and increased complexity of aviation and must be improved to maintain aviation safety. However, with significant improvement in this area, the safety objectives defined by international organizations can be achieved, and the risk of new incidents or accidents can be anticipated [12].

It is also important to note that introducing AI in ATMs raises some challenges and concerns, especially concerning data privacy and security, liability in case of errors, and the need for proper regulation. It is, therefore, essential to address these challenges to ensure an effective and safe implementation of AI in air traffic management. Furthermore, since AI can analyze large amounts of data and improve flight planning, fleet management, and cost optimization, it can also help airlines deliver better customer service by personalizing offers and resolving issues more efficiently.

NASA aviation research is exploring the possibility of using XAI technology to improve safety and efficiency in air transport of the future. Explainable AI (XAI) allows humans to understand how decisions are being made in autonomous systems, increasing trust in them and reducing the risk of unwanted errors. In addition, explainable AI can also be useful for the certification of autonomous systems and to ensure that appropriate regulatory standards are met. NASA aims to create a future in which autonomous vehicles can operate safely and efficiently in airspace, reduce congestion, and improve flight safety. XAI technology plays a crucial role in this goal by enabling humans to understand how decisions are being made in autonomous systems and providing greater transparency and trust in them [13, 14].

As the century has progressed, systems with AI have been more accepted and implemented for their versatility and relatively low implementation costs. The most representative benefit is the time gained with AI allowing tasks that previously required hours of manual work to be solved with algorithms quickly. The aerospace industry will also adopt the trend described above, so the lines of research in AI for autonomous applications may stand out with a more significant impact in academia[15].

In aeronautics, there are innovative technical and organizational systems called intelligent aviation systems, which provide more safety during the flight of an aircraft. The reason behind its development is the need to collect statistics on the leading causes of air accidents, such as the human factor, equipment failure, and external factors. A scientific problem related to assessing and predicting the threat of an accident is addressed. To solve this, it is suggested to use artificial intelligence to identify and prevent the immediate causes of an accident. These systems' technical characteristics, properties, and operating principles are described in detail, including intelligence, information, speed, controllability, the interdependence of subsystems, threat identification, accident prediction, and stopping [6].

With the introduction of new aviation technologies and new concepts of airspace organization, it seeks to provide communication between the airport and the aircraft. GSM technology checks weather conditions, runway parameters, and air traffic to reduce human errors and manual efforts. Then, before landing, the aircraft's arrival time is announced automatically [12]. The prospects of military aviators It is claimed that advanced technology in autonomy and artificial intelligence will likely result in the creation of pilotless aircraft and that this technological change could make military pilots a thing of the past.

Another important application of AI in aviation is data analytics. For example, AI can analyze large amounts of flight and aircraft maintenance data to identify trends and patterns, which can help predict failures and improve maintenance efficiency [12]. In the future, AI is expected to play an increasingly important role in aviation, helping to make air travel safer, more efficient, and more sustainable. With AI, it is possible to imagine a future in which airports run more smoothly and efficiently, flights are safer and more comfortable, and the aviation sector has a much smaller environmental impact.

Tabla 2. Examples of AI in applications and projects in different countries around the world.

Country	Areas of AI application	Examples of applications/project names
United States	Air traffic management, the workload of pilots and air traffic controllers	NASA Airspace Technology Demonstration 3, Federal Aviation Administration's Route Automation Modernization, Boeing Airpower Teaming System
China	Navigation and maintenance of commercial aircraft, autonomous drones	China's Commercial Aircraft Corporation C919, Autonomous Aerial Refueling
United Kingdom	Predictive aircraft maintenance, pilot training simulation, air traffic management	Rolls-Royce IntelligentEngine, NATS-iTEC Programme, Mixed Reality Training for Aircrew
Singapore	Management of aircraft maintenance and repair operations, design and production of more efficient and safer aircraft	Singapore Airlines Maintenance, Repair and Overhaul (MRO) Hub, Development of High-Performance Electric Propulsion System for Small Aircraft, Development of Supersonic UAV
France	Flight data analysis, air traffic planning optimization	SESAR Joint Undertaking, Thales Flight Management System, Data-driven Control and Surveillance of Air Traffic
Russia	Threat detection and security at airports, optimization of flight route planning	Sputnik, GLONASS, Integrated Security System for Airports
Australia	Aircraft maintenance, identification of faults and component problems	Qantas Group's Integrated Operations Centre, GE Aviation's Digital Collaboration Centre
Germany	Optimization of air traffic controllers' workload, air traffic planning	German Aerospace Centre's Digital Tower Solution, Electronic Flight Strips
Japan	Flight information management, flight route planning	Air Traffic Control by Augmented Reality, Route Control with the Support of AI and Big Data
United Arab Emirates	Airport security, threat detection, aircraft maintenance, component problem identification	Abu Dhabi Airports' Autonomous Wheelchair, Predictive Maintenance for Aircraft Systems, Enhanced Safety and Security Features in Dubai Airports

Table 2 provides valuable information on implementing artificial intelligence in aviation in different countries worldwide. Leading countries in the aviation industry, such as the United States, China, and France, are leading the way in implementing artificial intelligence in aviation. Most AI projects in aviation focus on improving safety and efficiency, including optimizing air traffic management, detecting anomalies, and monitoring aircraft health. AI-powered projects are being carried out by market-leading airlines and aircraft manufacturers, suggesting that the industry is leading innovation in this area above academia.

III.METHODOLOGY

The reference information was obtained from scientific literature obtained in repositories and scientific journals in the fields of engineering. In addition, a PRISMA review was carried out in which 15 documents were included for the study from a review of 116 papers from 4 scientific bases Web of Science, Science Direct, SCOPUS, and IEEE Xplore. The workflow is visualized in Figure 3.

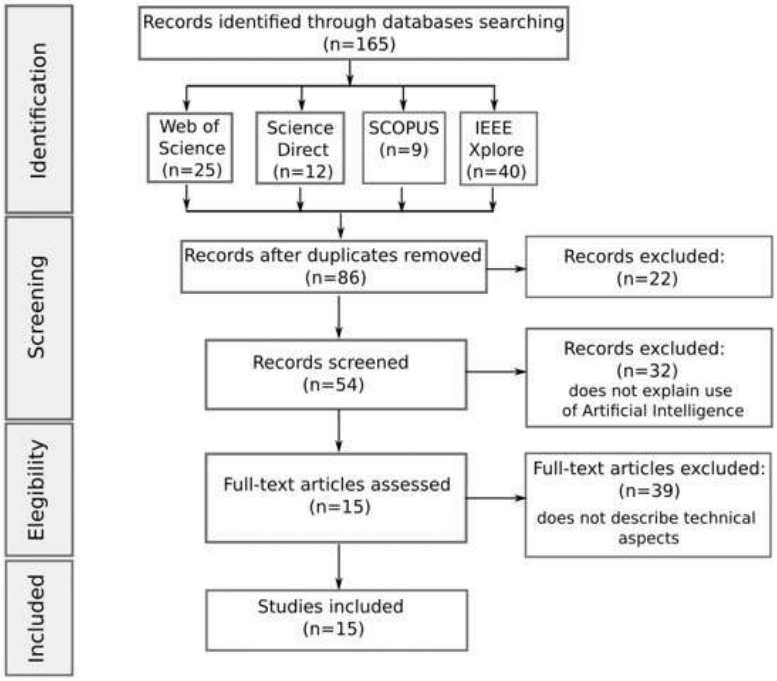

Fig. 3. Review workflow according to PRISMA methodology.

IV. RESULTS

The information presented in this paper presents essential findings on implementing artificial intelligence (AI) in the aviation industry. It is generally recognized that AI has significantly impacted aeronautics, improving efficiency, safety, and quality in the industry. AI can process large amounts of data and perform complex analyses to make accurate and fast decisions. However, the importance of supervision and regulation in implementing AI in aeronautics is also highlighted. Furthermore, it is recognized that AI can present risks if its use is not adequately monitored, and it is necessary to ensure the safety and well-being of all those involved in the aviation industry. Therefore, emphasis is placed on the need for proper regulation and close supervision to ensure that the implementation of AI in aeronautics is safe and effective.

The findings presented indicate that AI can be a valuable tool to improve efficiency and safety in the aviation industry. Still, its implementation must be adequately monitored and regulated to minimize potential risks.

Text in Calibri number 10. They must be those aspects product of the objectives set. The figures must have a description in the paragraphs near them. This same section includes the discussions of each result. Everything must be written in a harmonious and organized way.

CONCLUSIONS

The implementation of artificial intelligence in aeronautics has significantly improved the industry's efficiency, safety, and quality thanks to its ability to process large amounts of data and perform complex analyses. However, it is essential to note that aeronautics implementation requires close oversight and regulation to ensure the safety and well-being of everyone involved in the aviation industry. AI can present risks if its use needs to be adequately monitored.

Proper regulation and close oversight are necessary to ensure that the implementation of AI in aeronautics is safe and effective. This implies that regulatory authorities and aircraft manufacturers must work together to establish clear standards and robust oversight policies to ensure aviation safety and the well-being of those involved in the aviation industry.

Future applications of artificial intelligence in military aviation represent a significant advance in capability, efficiency, and operational safety. For example, AI can potentially improve the accuracy and speed of target reconnaissance and tracking systems, allowing military forces to identify and neutralize threats more effectively. In addition, AI algorithms can optimize flight paths and strategic resource deployment, maximizing the efficiency of military operations.

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ISSN-E: 2737-6419

Athenea Journal,
Vol. 4, Issue 12, (pp. 43-54)

https://doi.org/10.47460/athenea.v4i12.57

Advances in exoskeletons for military use

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Received (5/12/2022), Accepted (13/04/2023)

Abstract. - Development and use of exoskeletons worldwide have fostered many applications aimed at occupational health care and safety in multiple areas of industry, including the military. This article presents a systematic review of advances in exoskeletons used for various tasks performed by military personnel. In addition, a systematic review of scientific literature obtained from multidisciplinary bases and the field of occupational health has been carried out. Various technologies and exoskeleton designs assist in specific areas of the body where exertion can cause musculoskeletal disorders. Exoskeletons provide additional torque to multiple joints decreasing physical fatigue and increasing performance in physically demanding tasks. Most exoskeletons used in the military employ electric actuators and have been developed for the hip and knee region.

Keywords: Exoskeleton, assistance, physical performance, military activities, physical demand.

Avances en exoesqueletos para uso en el ámbito militar

Resumen: El desarrollo y uso de exoesqueletos a nivel mundial ha fomentado un sin número de aplicaciones direccionadas al cuidado de la salud y seguridad ocupacional en múltiples ámbitos de la industria incluyendo el ámbito militar. En este artículo se presenta una revisión sistemática de los avances en exoesqueletos que se emplean para múltiples tareas realizadas por el personal militar. Se ha realizado una revisión sistemática de literatura científica obtenida de bases multidisciplinarias y del ámbito de la salud ocupacional. Existe una variedad de tecnologías y diseños de exoesqueletos que brindan asistencia en zonas específicas del cuerpo en donde el esfuerzo puede provocar trastornos musculoesqueléticos. Los exoesqueletos brindan un par adicional a múltiples articulaciones disminuyendo la fatiga física y aumentando el rendimiento en tareas de alta exigencia física. La mayoría de los exoesqueletos usados en el ámbito militar emplean actuadores eléctricos y se han desarrollado para la región de la cadera y rodillas.

Palabras clave: Exoesqueleto, asistencia, rendimiento físico, actividades militares, exigencia física.

I. INTRODUCTION

Exoskeletons are devices that, through electric, pneumatic, hydraulic, or mechanical actuators, provide support to the joints and musculoskeletal systems of the human body by mimicking and driving movements and allowing them to reducing the physical load during the execution of specific repetitive tasks. The primary function of exoskeletons is to help the structure of users hold or manipulate loads and prevent excessive efforts from being concentrated in areas such as the hip, shoulders, knee, back, legs, etc. [1]. Exoskeletons are often required to perform tasks in medicine, industry, military, security, and others that need high physical demand. In addition to this, these devices have been designed to assist people with disabilities or physical mobility limitations. The developments of exoskeletons focus on providing a more natural movement, reducing the devices to more superficial structures, and achieving operation with lower energy consumption to extend their autonomy.

In the military, exoskeletons increase the strength and mobility of active members in campaign and conflict zones. With the advancement of technology in assistance exoskeletons and the development of more efficient actuators, greater importance has been given to implementing these devices in defense and security[2]. Performance improvements have been evidenced in tasks related to the handling of loads and prolonged movements in walks mainly.

In recent years, exoskeletons and exosuits have been used mainly by the medical, industrial, and military industries. Although they have been used for some years to enhance occupational health and safety in workers, there is still insufficient evidence of the physical interaction between the exoskeleton and the human being (pHEI). Assessing pHEI is essential for accepting and using these devices on a large scale. Research into robotic exoskeletons has been very active in the last decade due to advances in hardware, efficiency, and power supply. Since 1960, the study of these devices has sought to combine the human body and a robotic system to provide protection and support, improving the user's athletic ability and muscular endurance [3].

Despite developments in exoskeletons, there are still significant limitations to their practical use, including inefficient actuator power systems and their impact on occupational safety. Nevertheless, the story of exoskeletons has become an essential line of research in robotics.

Table 1 presents in a general way the most frequent types of exoskeletons from the point of view of applicability in the military field, the parts of the body that are assisted by this device, the technologies used, and their frequent applications in which they are used by military personnel [4].

Table 1. Technological aspects addressed by Industry 4.0 in aviation.

Exoskeleton Type	Assisted body parts	Technology	Frequent applications
Loading exoskeleton	Back, shoulders, and legs	Hydraulic, pneumatic, or electrical systems	Transport of heavy loads
Limb support exoskeleton	Legs, arms, and hands	Sensors, motors, and control systems	Improved movement and precision, reduced muscle fatigue
Protective exoskeleton	Whole body or specific parts	Ballistic materials and shock absorption systems	Protection against injury from explosions, bullet impacts, and debris
Rehabilitation exoskeleton	Legs and arms	Sensors, motors, and control systems	Injury and Disability Rehabilitation

An increasing variety of societal needs justifies the expanding development of exoskeletons. The growing population of people with movement disabilities due to stroke, spinal cord injury, or other related diseases has driven the demand for devices that can improve their quality of life, helping them regain the ability to walk independently [4]. On the other hand, devices that can increase the physical capabilities of people without disabilities are also required to improve their performance in the military field. In the last decade, exoskeletons and robotic assistive devices have made significant progress in making commercially available products. The exoskeletons applied in the military field have five categories that depend on their application. These are Full body Military Exoskeletons, Lower Body Powered Military Exoskeletons, Passive Military Exoskeletons, Energy Scavenging, and Stationary Military Exoskeletons.

Entire body Military Exoskeletons are a category of exoskeletons that cover the soldier's whole body, from head to toe. These exoskeletons provide complete protection against injury and explosions and are often combined with communication and life support systems to increase the soldier's survivability on the battlefield. Lower Body Powered Military Exoskeletons are designed to assist and improve the mobility of a soldier's legs and pelvis[5]. These exoskeletons use electric or hydraulic motors to support the legs, increasing muscular strength and endurance and reducing fatigue. Passive military exoskeletons are military exoskeletons that do not require any external power source; instead, they use passive technologies, such as springs and shock-absorbing materials, to reduce the load on the soldier's body and improve mobility and endurance. Finally, stationary military exoskeletons are used for static and specific tasks, such as handling heavy loads in a stagnant environment. These exoskeletons are anchored to a fixed platform or structure, such as a vehicle, work platform, or military installation, and provide support to reduce fatigue and increase the soldier's endurance.

The movements generated by the actuators of the exoskeletons, in the case of active exoskeletons, must be entirely controlled by electronic systems that are responsible for activating or deactivating them depending on the intention of movement of the limbs or positions adopted by the user of the device. In terms of application, exoskeleton controllers are equipped with task controllers that can be adapted in different ways to meet other goals. Maintaining good safety and health conditions for military members is a crucial aspect. In their routine activities, soldiers must often carry heavy equipment during their missions, prone to musculoskeletal affectations in the back region despite their continuous physical preparation. Therefore, the interest of the military field is in searching for, developing, and implementing new technologies such as exoskeletons [5].

The increase in physical activity of wars and conflicts today has resulted in a more significant load and demand for soldiers, which has promoted solutions such as exoskeletons to ensure better performance and chances of injury during field operations relieving overload and improving the physical capacity of soldiers,, reducing your oxygen consumption and increasing your energy to perform tasks such as walking, running, and jumping. Among the best-known exoskeletons are the Berkeley Lower Extremity Exoskeleton (BLEEX), Raytheon XOS, Human Universal Load Carrier (HULC), and Hybrid Assisted Limb (HAL). The U.S. Defense Advanced Research Projects Agency (DARPA) uses the first three as individual combat exoskeletons, while the HAL is also used outside the military [6].

In the development section, this document explains the technologies used in the models of exoskeletons used in the military field. The Methodologies section describes how the information was obtained from the scientific literature. The results section comments on the findings and new technologies, addressing multiple viewpoints and finally presenting the conclusions.

II. DEVELOPMENT

Exoskeletons in recent decades and within the military have been implemented in applications such as personal protection, cargo assistance, mobility improvement, and rehabilitation. Advances in exoskeleton technology have led to the creation of more advanced and practical models, and it is expected that their use will continue to expand in the future as well as that the academy will strengthen these lines of research by enhancing unexplored areas to improve human interaction with these devices [3].

Table 2 presents the aspects identified in scientific literature according to the characteristics or lines of research related to developing exoskeletons for the military field, whose criteria are also used in the industry in general [7].

Table 2. Areas of research related to developing projects in exoskeletons for the military field.

Research aspects in military exoskeletons	Description
Design and development of exoskeletons	Research into the design and development of safe, reliable, comfortable, and effective military exoskeletons that reduce physical load and improve soldier performance.
Clinical and ergonomic evaluation	Conducting clinical and ergonomic studies to evaluate the efficacy and safety of exoskeletons in alleviating physical load and preventing injury to the soldier. Identify best practices regarding the adaptation, training, and use of exoskeletons.
Development of control algorithms	Research into developing control algorithms and human-machine interface software that can improve the accuracy and efficiency of exoskeletons and enable better interaction between the user and the exoskeleton.
Integration of exoskeletons with other systems	Research into integrating exoskeletons with other military systems, such as weapons, communication systems, and vehicles. Identification of interoperability requirements and assessment of the impact of exoskeleton integration on operational effectiveness and efficiency.

Of the four areas in Table 2, most studies show a frequent site that connects skeletons with the study of humans, which is robotics (Fig. 1). The participation of multiple disciplines is evidenced, such as mechanical design, human engineering, control and electronics, physiology, human-computer interaction, etc. In addition, the United States' significant contribution to these investigations and developments is highlighted. Most studies consider robotic wireless technology systems for lower extremity support. Artificial intelligence has been incorporated into these developments to improve motion control, user interaction, and experiences [8].

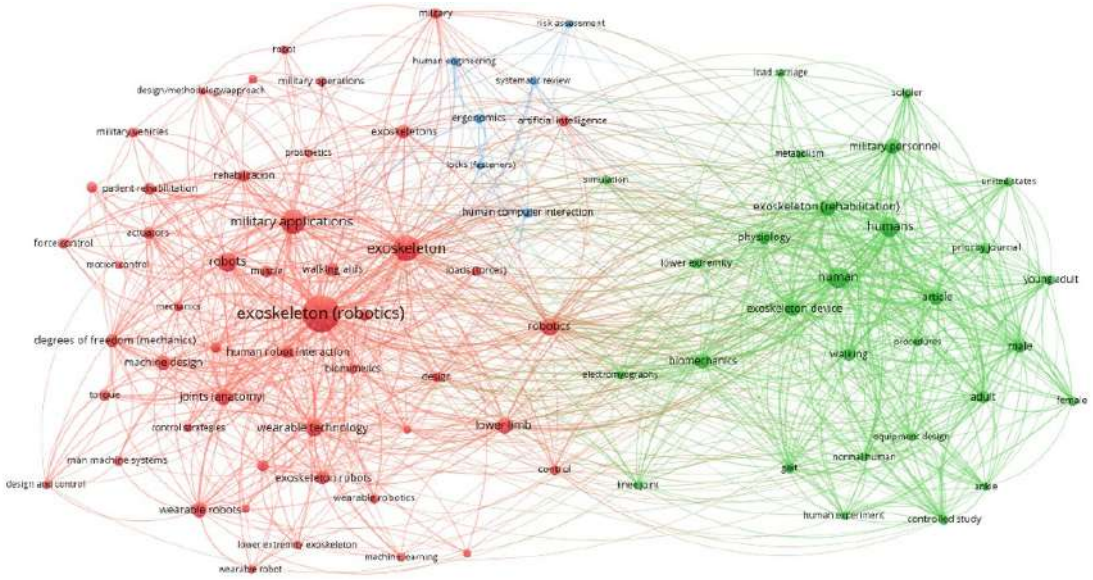

Fig. 1. Bibliometric graph of occurrence of keywords in 200 studies of exoskeletons that mention military applications Considering the base of SCOPUS (last ten years), graphics made with VOSviewer®

Military exoskeletons have focused on assisting certain limbs and specific body areas compromised by the realization of great physical exertion and muscle fatigue due to repetitive movements.

Exoskeletons for the military focus on assisting the following parts of the human body: elbow-shoulder, shoulder, hip, ankle-knee-hip, knee, and spine [9]. Figure 2 presents illustrations of exoskeletons with structures similar to those used with current technologies in military personnel.

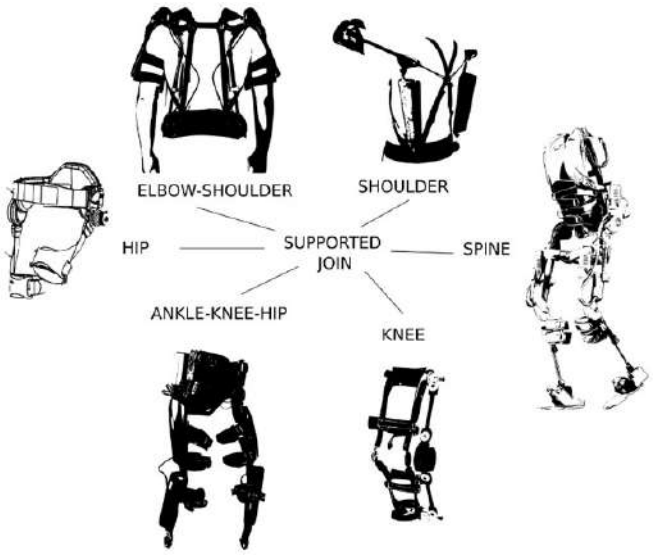

Fig. 2. Bibliometric graph of occurrence of keywords in 200 studies of exoskeletons that mention military applications Considering the base of SCOPUS (last ten years), graphics made with VOSviewer®

Technologies employed in exoskeletons have been linked to the actuators that provide additional torque when the user requires it for their movement. Motion transmissions include actuators: cable driven, hypoid gear, variable stiffness actuator, springs BoC, pneumatic, hydraulic, passive, and electric [2].

The United States, Russia, Israel, China, and South Korea lead the most significant investment in exoskeleton research and development projects. The United States has invested significantly in the research and development of military exoskeletons to reduce the physical burden on its soldiers and improve their battlefield performance. It has also established collaborative programs with universities and companies to accelerate the development of advanced exoskeletons. Russia: Russian industry has been working on the development of military exoskeletons for several years now. Russian exoskeletons have been used in military exercises and are expected to be used in real missions [10]. Israel has invested in developing military exoskeletons to improve its soldiers' mobility and carrying capacity. Israel has developed lightweight and portable exoskeletons that can be adapted to different tasks on the battlefield. China has invested in research and development of military exoskeletons to improve the performance of its soldiers. Chinese exoskeletons have been used in military exercises and are expected to be used in real missions. South Korea has been developing military exoskeletons to improve its soldiers' carrying capacity and mobility. Korean exoskeletons have been used in military exercises and are expected to be used in actual missions [11]. It should be noted that other countries in Europe and Asia are working on the research and development of military exoskeletons, although to a lesser extent than those mentioned above.

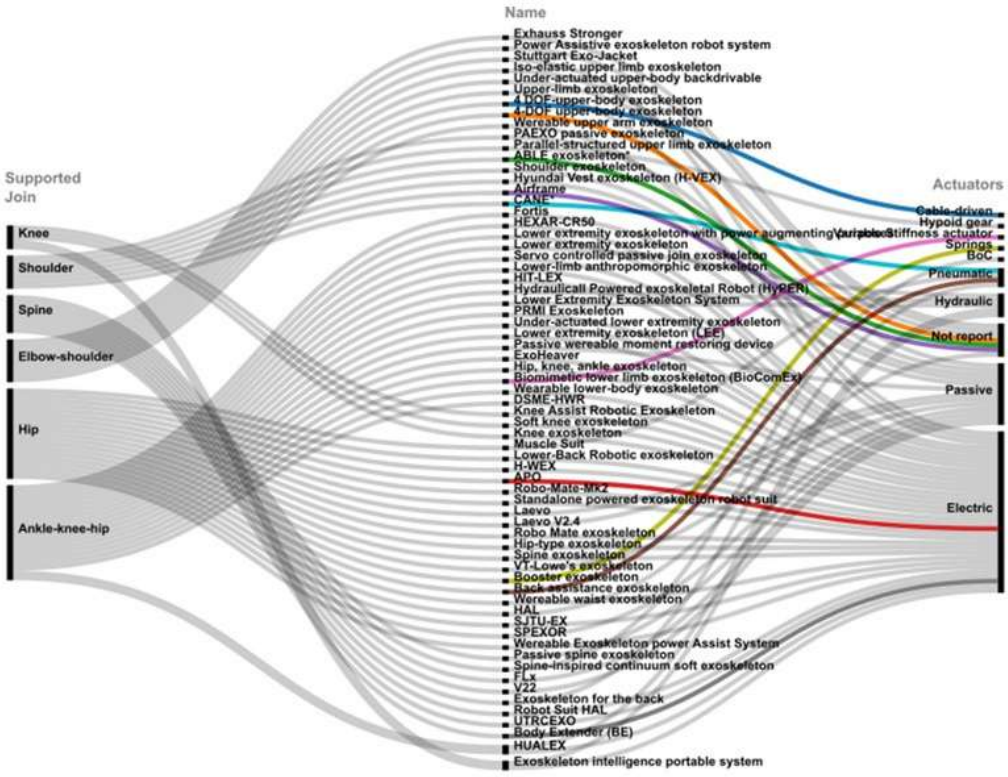

Fig. 3. Types of actuators and exoskeletons developed for assistance according to the parts of the human body.

Figure 3 presents multiple developments of exoskeletons driven by the countries that most research and produce them. Although the devices in Figure 3 are commercial and used in the military field, the type of assisted joint, the name or model of the device, and the type of actuator used are specified in the graph.

The adoption of exoskeletons and their military use raises ethical and social concerns that need to be addressed by ethicists, industry, and society at large. These concerns include the personal and psychological impact on disabled people and their families, access to expensive technology, and the dependency it can generate [12]. One of the concerns is that the extensive use of exoskeletons on soldiers could promote an increased workload of personnel and dehumanize activities during wars and conflicts. These problems have no easy solutions and may require regulatory solutions or cost reduction as technology becomes more accessible. But in general, exoskeletons and other human enhancement technologies raise complex questions that force us to redefine our perception of humanity and ourselves.

Evidence shows that wearing custom exoskeletons during a military obstacle course resulted in better overall performance than a condition without an exoskeleton. However, some obstacles, such as going up and down stairs, hatches, and tunnels, were performed more slowly with the exoskeleton. In addition, while weight acceptability and torso stiffness were similar in both conditions, overall performance acceptability was better without the exoskeleton.

Table 3 presents the most advanced exoskeletons that use state-of-the-art technology and are used by the armies of the most developed countries to support their military personnel. The name of the devices, the country of origin, and the most frequent applications in the military field are described [13].

Table. 3. Most technologically advanced exoskeletons used by the world's armies.

Country	Areas of AI application	Examples of applications/project names
United States	Air traffic management, the workload of pilots and air traffic controllers	NASA Airspace Technology Demonstration 3, Federal Aviation Administration's Route Automation Modernization, Boeing Airpower Teaming System
China	Navigation and maintenance of commercial aircraft, autonomous drones	China's Commercial Aircraft Corporation C919, Autonomous Aerial Refueling
United Kingdom	Predictive aircraft maintenance, pilot training simulation, air traffic management	Rolls-Royce IntelligentEngine, NATS-iTEC Programme, Mixed Reality Training for Aircrew
Singapore	Management of aircraft maintenance and repair operations, design and production of more efficient and safer aircraft	Singapore Airlines Maintenance, Repair and Overhaul (MRO) Hub, Development of High-Performance Electric Propulsion System for Small Aircraft, Development of Supersonic UAV
France	Flight data analysis, air traffic planning optimization	SESAR Joint Undertaking, Thales Flight Management System, Data-driven Control and Surveillance of Air Traffic
Russia	Threat detection and security at airports, optimization of flight route planning	Sputnik, GLONASS, Integrated Security System for Airports
Australia	Aircraft maintenance, identification of faults and component problems	Qantas Group's Integrated Operations Centre, GE Aviation's Digital Collaboration Centre
Germany	Optimization of air traffic controllers' workload, air traffic planning	German Aerospace Centre's Digital Tower Solution, Electronic Flight Strips
Japan	Flight information management, flight route planning	Air Traffic Control by Augmented Reality, Route Control with the Support of AI and Big Data
United Arab Emirates	Airport security, threat detection, aircraft maintenance, component problem identification	Abu Dhabi Airports' Autonomous Wheelchair, Predictive Maintenance for Aircraft Systems, Enhanced Safety and Security Features in Dubai Airports

Analyzing the above table of military exoskeletons, some interesting trends and patterns can be observed regarding the technology and its application in the military field. First, most exoskeletons are designed to improve soldiers' mobility and strength and help lift and carry heavy loads. This suggests that one of the main goals of military exoskeleton technology is to increase soldiers' physical capacity and endurance in combat situations.

Various countries are developing advanced military exoskeletons, with the United States leading the way in the number of exoskeletons produced. This suggests a significant investment and resources devoted to researching and developing military exoskeleton technology.

A variety of specific applications are evident for different military exoskeletons. For example, some are designed specifically for protection, while others are designed to improve soldiers' mobility and strength. This suggests that there are a host of different approaches to the design and implementation of military exoskeleton technology and that exoskeletons may have a variety of specific applications in different military contexts. Furthermore, modern technology also empowers using artificial intelligence (AI) in exoskeletons to improve the efficiency, accuracy, and responsiveness of exoskeleton control and feedback systems and detect and fix potential problems before they become significant problems [8].

Some studies show the impact of using exoskeletons in the military field. For example, an improvement in strength and endurance has been determined according to a 2017 study published in the Journal of Biomechanics, which determined that using exoskeletons increased soldiers' strength and endurance by 27% and 23%, respectively [14]. Furthermore, a 2020 study published in the Journal of Military Medicine has reduced the risk of injury. It was found that using exoskeletons reduced pain in the back and legs by 41% and 39%, respectively. In addition, participants reported less fatigue after wearing the exoskeletons, suggesting they can help prevent injuries in combat situations [14].

There was an increase in efficiency, according to a 2019 article published in the Journal of Human Performance in Extreme Environments which determined that using exoskeletons reduced the time needed to complete cargo transport tasks by 19%. In addition, participants reported reduced perceived exertion and greater task efficiency when wearing exoskeletons [15]. Furthermore, the improvement in precision and stability has been evidenced according to the article in the Journal of Neuroengineering and Rehabilitation, in which it was found that the use of exoskeletons improved the precision and stability of the user's movements by 29% and 23%, respectively. Additionally, participants reported greater accuracy and control in delicate hand and finger movements when wearing exoskeletons.

III. METHODOLOGY

The information from scientific literature has been obtained from articles of previous reviews published in scientific repositories and databases such as SCOPUS, IEEE, and Science Direct. In addition, articles were screened that will not describe military applications of exoskeletons and that were not related to tasks common to this field, considering routine field activities and requiring considerable physical demand. A total of 14 reference works were carried out to develop this article. The documents reviewed corresponded to the period of the last five years.

Figure 4 describes the workflow in selecting the articles considered for this study that provide input in the identification of military exoskeletons on developments of the last five years in several countries of the world and for multiple parts of the body that are assisted with these technologies. Open access documents were considered based on "military AND exoskeleton." To obtain information, open-access documents, reviews, overviews, and original research were considered, and conference papers were excluded.

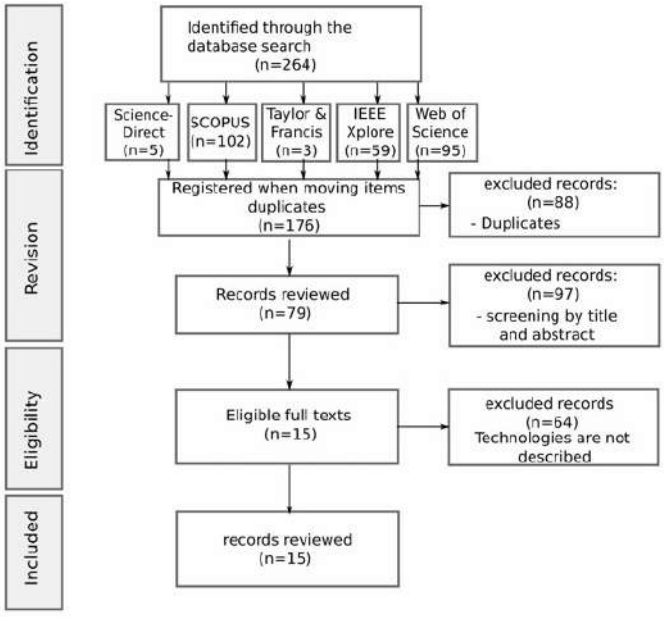

Fig. 4. Workflow in identifying the selected articles based on the guidelines of the PRISMA methodologies.

IV. RESULTADOS

This review article has identified the exoskeletons used in the military field and the type of assistance it provides, especially to soldiers and their operating technologies. It has been described as the contribution to the conditions of safety and occupational health that contribute while performing tasks of high physical demand. The advantages and disadvantages of the use of these technologies are identified. The line of research in exoskeletons has generated interest in recent years. One of the most important aspects is the interaction and comfort of using these devices.

Significant progress has been made in developing exoskeletons for use in the military. One of the most significant advances has been the miniaturization of the systems, creating more portable exoskeletons adaptable to different combat situations. In addition, incorporating sensors and artificial intelligence systems have improved the ability of exoskeletons to adapt to the needs of soldiers and provide personalized support in real-time. Another critical advance that has been identified has been the development of exoskeletons with flight capabilities, which can be helpful for reconnaissance and surveillance missions. Work has also been done on creating exoskeletons that can provide medical support on the battlefield, such as devices that stabilize fractures and prevent further limb damage. Overall, these advances improve soldiers' ability to accomplish their missions and reduce the risk of injuries and illnesses related to physical and mental stress on the battlefield. Table 1 shows the advantages and disadvantages observed in the use of exoskeletons in the military environment.

Table. 4. Workflow in identifying the selected articles based on the guidelines of the PRISMA methodologies.

Advantages of exoskeletons in the military field	Disadvantages of exoskeletons in the military
Increased strength and physical endurance	Development and acquisition cost
Additional protection against injuries and threats	Weight and volume of the device
Improved accuracy and stability	Need for power supply.
Facilitates the transport of heavy loads	Adaptation to different operating environments
Logistic applications in maintenance tasks	Limitations in mobility and agility

The exoskeletons most developed in the last decade are electrical due to the ease of implementing these technologies and microelectronics developments that advance the best use of electrical energy. The actuators of these exoskeletons are characterized by their operation with direct current and have a structure similar to that of Figure 5.

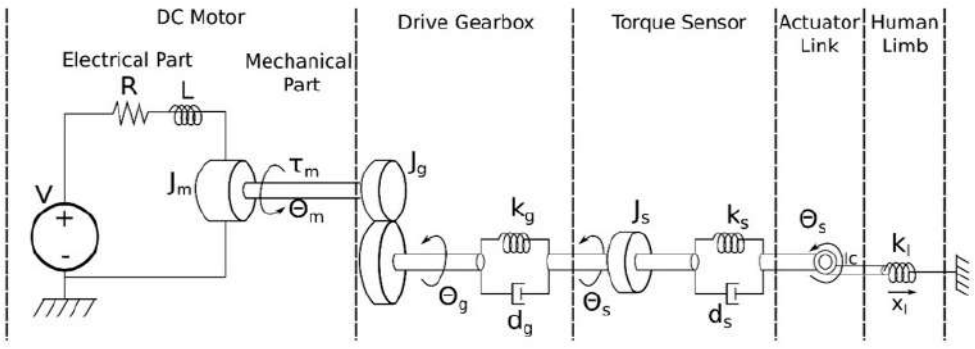

Fig. 5. Schematic representation of the electrical, electronic, and mechanical components that make up the control system of electric actuators in torsion-assisted electric exoskeletons.

Where V represents the source of direct electrical energy; R is the resistance of the electrical system; L is the inductance of the electrical system; J is the rotational inertia, Θ the angle of rotation; d is the damping K the induction constant used and X is the displacement of the limb or joint that moves with the exoskeleton.

Table. 5. Effort-work relationship in the design of exoskeletons.

Mechanical Effort	Physical Work
Exoskeletons reduce physical exertion.	Exoskeletons perform mechanical work.
Help lift and carry heavy loads.	Perform repetitive tasks in an assisted manner.
Allow movements with less fatigue.	Contribute to carrying out activities more efficiently.
Reduce tension and stress in the body	Help maintain productivity in physically demanding tasks
Improve muscle endurance	Facilitate performing physical tasks for extended periods.

Exoskeletons reduce users' physical effort, helping them perform physical tasks more efficiently and with less fatigue. On the other hand, exoskeletons also serve mechanical work by assisting users in the execution of tasks, such as lifting heavy loads or performing repetitive movements.

Table 6 shows the most important aspects considered in the design of exoskeletons. These are essential considerations in creating military exoskeletons, as they affect functionality and user experience. For example, exoskeletons must be ergonomic, durable, and easy to use while offering mobility, protection, and compatibility with other equipment used by soldiers. In addition, energy autonomy and communication capacity are essential factors to maximize effectiveness on the battlefield.

Table. 6. Factors to consider in the design of exoskeletons.

Aspect	Description
Ergonomics	Design that fits comfortably to the human body, minimizing discomfort and fatigue.
Mobility	Ability to allow natural and broad movements for optimal functionality.
Strength and durability	Rugged construction and durable materials to withstand the demands of military use.
Adjustability	Possibility to adjust the exoskeleton to suit different users and body sizes.
Compatibility with military equipment	Design that allows simultaneous use of other equipment and standard soldiers' armament.
Ease of use	Intuitive and easy to use for soldiers, without requiring prolonged training.
Power supply	Efficient battery systems or alternative energy sources for adequate autonomy.
Threat Protection	Integration of ballistic, thermal, or chemical protection technologies, as needed.
Connectivity and communication	Wireless communication capabilities to interconnect devices and share information.

CONCLUSIONS

The use of exoskeletons in the military is a complex and controversial topic that requires careful evaluation of the potential benefits and risks. Therefore, it is crucial that rigorous research is conducted and that the ethics and legality of using these devices are carefully considered before making decisions about their implementation in the military field.

Exoskeletons can improve the efficiency and capability of soldiers on the battlefield. By providing greater strength, endurance, and protection, exoskeletons can allow soldiers to carry more weight and maintain high performance for extended periods. Exoskeletons can also reduce the risk of injuries and illnesses related to physical and mental stress on the battlefield. This can include back, shoulder, and knee injuries, heat-related illnesses, and fatigue.

Although exoskeletons have great potential to improve soldiers' ability on the battlefield, they also present some challenges. This includes the cost, the need for energy for its operation, and the complexity of the technology. In addition, it is important to consider ethical risks and concerns about reliance on technology on the battlefield.

Exoskeletons have been explored as a promising technology to improve soldiers' strength, endurance, and protection in the military field. They can provide soldiers with greater strength and physical endurance, allowing them to carry and handle heavy loads more efficiently. In addition, these devices can reduce muscle fatigue and help avoid injuries associated with transporting heavy equipment over long distances.

There are developments designed to provide additional protection to soldiers. They may include features such as integrated armor plates or shock absorption systems to protect the user against injury caused by explosions, debris, or projectiles. But they can also help improve soldiers' accuracy and stability by reducing tremors and unwanted movements. This can be especially beneficial for activities that require precise aim, such as using firearms or handling delicate equipment.

Exoskeletons can also have logistical applications in the military field. For example, they can facilitate the loading and unloading of supplies, equipment maintenance and repair, and construction tasks in rugged terrain. However, despite the potential benefits, there are challenges associated with using exoskeletons in military affairs. The challenges include the cost of developing and acquiring the devices, their weight and volume, the need for power supply, and adapting to different operating environments.

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$$(x+a)^n = \sum_{k=0}^{n} \binom{n}{k} x^k a^{n-k}$$

$$(1+x)^n = 1 + \frac{nx}{1!} + \frac{n(n-1)x^2}{2!} + \cdots$$

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