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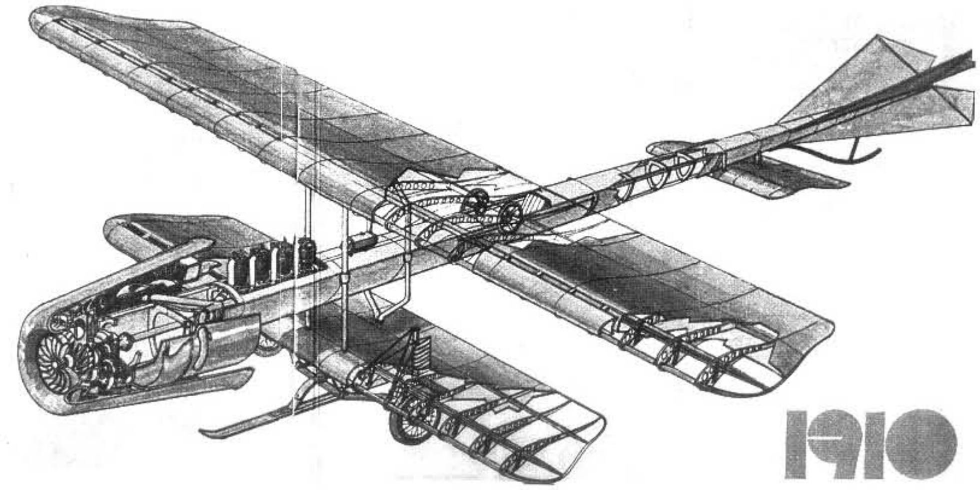

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C O N T E N T S

UNLEASHING THE POWER OF DATA: THE SIGNIFICANCE OF ANALYSIS AND PREDICTION

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Abstract: *In the era of data-driven decision making, this article explores the transformative impact of data analytics and prediction on various industries and sectors. From discovering hidden patterns to making informed decisions, the article explores the fundamental principles and real-world applications of data analytics. Additionally, it highlights the predictive capabilities of machine learning and the role of data-driven insights in shaping the future. As we explore the benefits, challenges and ethical considerations, the article aims to outline the indispensable role of data analytics and prediction in navigating the complexities of our dynamic and competitive world.*

Keywords: *Data Analytics, Prediction, Machine Learning, Data-Driven Decision Making, Transformative Impact, Hidden Patterns, Informed Decisions, Real World Applications, Predictive Analytics, Future Trends, Benefits, Challenges, Ethical Considerations, Competitive Landscape.*

1. INTRODUCTION

In today's landscape, where every click, transaction and interaction generates a digital footprint, big data has become an invaluable asset. In this age of information abundance, the ability to extract meaningful information from data is not only advantageous; it is now becoming a necessity. The article "Unleashing the Power of Data: The Importance of Analytics and Prediction" aims to reveal the profound impact that data analytics and prediction have on various fields.

As organizations face unprecedented amounts of information, the key to staying ahead lies in using this data effectively. From unraveling complicated patterns to making data-driven predictions, the capabilities of modern analytics are transforming industries and decision-making processes. In this exploration, we delve into the fundamental principles of data analytics, shedding light on its real-world applications. Additionally, we navigate the realm of prediction, where machine learning algorithms predict trends and reveal potential outcomes.[1]

Beyond the immediate benefits, this article looks at the broader implications of data analysis and prediction. We discuss how these practices give decision makers the tools to make informed choices, optimize resources and gain a competitive advantage. However, as we traverse this data-driven landscape, we also face challenges, touching on issues of privacy, security, bias, and ethical considerations.

In the pages that follow, we reveal the significance of data analytics and prediction in shaping our interconnected world.

From increasing efficiency to anticipating future trends, the power of data lies not only in its sheer volume, but also in the strategic insights it provides.

Join us on this exploration into the heart of data's transformative influence, where analytics and prediction pave the way for informed, strategic and impactful decision-making. [2]

2. UNDERSTANDING DATA ANALYSIS

A. Definition and basic elements

- Data Analysis Defined: Data analysis is the systematic process of inspecting, cleaning, transforming and modeling data to uncover useful information, draw conclusions and support decision making. It involves a variety of techniques and methods to discover patterns, relationships and trends in data sets.
- Fundamental principles: Purpose-driven: Data analysis serves a specific purpose, whether it is to identify market trends, optimize business processes, or anticipate future outcomes.
- Iterative process: Analysis often involves iterating steps to refine models and continuously improve insights.
- Quantitative and qualitative: Data analysis can be both quantitative (dealing with numerical data) and qualitative (exploring non-numerical information such as text or images).
- Foundation of Statistics: Statistical methods form the backbone of many data analysis techniques, providing tools to make inferences and predictions.

B. Data analysis process

1. Data collection:

➢ Structured data: Organized in a tabular format with predefined categories.
➢ Unstructured data: Lacks a predefined data model, including text, images and videos.
➢ Data Sources: Varied and include databases, surveys, sensors, social networks, and more.

2. Data cleaning:

➢ Error detection: Detect and rectify inaccuracies, inconsistencies and missing values.
➢ Normalization: Ensuring uniformity in data representation.

3. Data processing:

➢ Aggregation: combining data to create summary statistics.
➢ Transformation: converting data into a suitable format for analysis.

4. Data analysis:

➢ Descriptive analysis: Summarizing and presenting the key features of the data. Inferential analysis: Making predictions or inferences about a population based on a sample.
➢ Exploratory Data Analysis (EDA): Investigating data sets to identify patterns or relationships. [3]

C. Real world application

Data analytics finds applications in various sectors, revolutionizing the way industries work:

1. Medical assistance:

➢ Predictive analysis helps in disease outbreak prediction.
➢ Analysis of patient records improves personalized treatment plans.

2. Finances:
- Risk assessment models inform investment decisions.
- Fraud detection systems analyze transaction patterns.

3. Marketing:
- Customer segmentation identifies the target audience.
- Analysis of campaign performance guides future marketing strategies.

As we explore each facet of data analytics, from its fundamental principles to practical applications, it becomes apparent that this foray from raw data to actionable insights is both nuanced and powerful. [4]

3. THE POWER OF PREDICTION

A. Introduction to prediction

Definition of Prediction: Prediction is the process of using data, statistical algorithms and machine learning techniques to identify the probability of future outcomes. It plays a critical role in unlocking the potential of data, providing insight into what might happen and facilitating informed decision-making.

The Role of Prediction in Using Data: Prediction empowers organizations to go beyond retrospective analysis and proactively anticipate future trends. By leveraging historical data and patterns, individuals can make strategic decisions to reduce risks and capitalize on opportunities. Prediction transforms data from a simple historical record into a powerful tool for shaping the future.

Descriptive Analysis vs. Predictive Analytics: Descriptive analytics focuses on summarizing historical data to gain insights into what happened. Instead, predictive analytics goes a step further, using statistical models and machine learning algorithms to forecast future outcomes. While descriptive analytics provides retrospective insight, predictive analytics provides forward-looking insight, enabling organizations to act with precision. [5]

B. Automatic learning and predictive modeling

Role of Machine Learning: Machine learning algorithms are at the forefront of predictive modeling. These algorithms learn from patterns in historical data and use them to make predictions or decisions without explicit programming. Machine Learning's ability to adapt and improve over time makes it a powerful tool for accurate and dynamic predictions.

Examples of Predictive Analytics in Action:

Fraud Detection: Predictive analytics is used extensively in financial sectors to detect fraudulent activities. Machine Learning algorithms analyze transaction patterns, identify anomalies and flag potentially fraudulent transactions in real time.

Recommender Systems: Platforms like Netflix and Amazon use predictive modeling to recommend content or products based on users' historical preferences. These systems analyze user behavior and preferences to predict future choices. [6]

C. Future trends in prediction

Emerging Technologies:

Artificial Intelligence (AI): AI, especially in the form of advanced neural networks and deep learning models, is revolutionizing predictive analytics. AI can process large amounts of intangible data, discover complex patterns and improve the accuracy of predictions.

Deep Learning: Deep learning, a sub-branch of machine learning, involves multi-layered neural networks that excel at extracting intricate features from data, making it a powerful tool for complex predictive modeling.

Shaping the Future of Predictive Analytics: The future of predictive analytics is full of exciting prospects, spurred by continued advances in AI, deep learning, and other cutting-edge technologies.

The ability to use these tools will not only refine predictions, but also open up new opportunities for innovation, efficiency and strategic decision-making. In conclusion, prediction is a dynamic force that transforms data into actionable insights, guiding organizations toward a future defined by informed choices and strategic foresight. As we adopt emerging technologies, the landscape of predictive analytics is poised to evolve, providing unprecedented capabilities and opportunities for those who harness its power.

4. BENEFITS OF DATA ANALYSIS AND PREDICTION

A. Informed decision making

How Data Analytics and Prediction Empower Informed Decision Making: Data analytics and prediction provide a solid foundation for informed and strategic decision making within organizations. By thoroughly evaluating historical data and anticipating future outcomes, decision makers can make decisions with confidence, with a solid and proactive framework for business guidance.

B. Improved efficiency and optimization of resources

How these practices help optimize resources, reduce costs and improve efficiency: Data analysis and prediction play a crucial role in optimizing resource utilization and increasing operational efficiency. By assessing resource requirements and availability, organizations can identify opportunities to save costs, reduce waste, and improve productivity. [7],[8]

C. Identifying patterns and trends

How data analysis uncovers hidden patterns and trends: Data analysis has the ability to uncover hidden patterns and trends that may not be apparent through traditional methods. By using algorithms and predictive models, organizations can detect complex connections and relationships between variables, providing a deeper understanding of data behavior.

In conclusion, the benefits of data analytics and prediction extend beyond simply generating insights. These practices provide organizations with powerful tools for making wise decisions, optimizing resource utilization, and uncovering new and valuable data insights. By integrating these processes strategically, organizations become more agile, efficient and prepared to meet the challenges of an ever-changing business environment.

5. CHALLENGES AND ETHICAL CONSIDERATIONS

A. Privacy And Data Security

Addressing Data Privacy and Security Concerns in the Era of Big Data Analytics: In an era where data analytics is becoming more pervasive, data privacy and security concerns are inevitable. With access to massive volumes of information, organizations face challenges in ensuring the confidentiality of customer data and other sensitive information. It is crucial to implement rigorous security measures and comply with data protection rules and regulations to prevent security incidents and maintain user trust.

B. Bias And Fairness

Discussion of the potential that BIAS can have in data analysis and the importance of correctness in predictive models: Data analysis can bring with it the risk of introducing biases into predictive models. This may be the result of different data sets, data collection methods or inappropriate choice of features. It is essential to recognize these biases and pay special attention to the accuracy of predictive models.

Ensuring fair and non-discriminatory treatment for all users is fundamental to building ethical analytics and prediction systems.

In conclusion, as the benefits of data analysis and prediction are explored, it is important to face and address the associated challenges and ethical issues. Protecting data privacy and security, as well as managing bias and ensuring fairness, are essential pillars for the development and sustainable implementation of analytical practices in modern society. [9],[10]

6. SOFTWARE APPLICATION (SIMPLE LINEAR REGRESSION MODEL)

A. Simple Linear Regression Model – Python Language

```
import numpy as np
import pandas as pd
from sklearn.model_selection import train_test_split
from sklearn.linear_model import LinearRegression
from sklearn.metrics import mean_squared_error
import matplotlib.pyplot as plt
np.random.seed(42)
X = 2 * np.random.rand(100, 1)
y = 4 + 3 * X + np.random.randn(100, 1)
data = pd.DataFrame(data=np.column_stack((X, y)), columns=['X', 'y'])
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)
model = LinearRegression()
model.fit(X_train, y_train)
y_pred = model.predict(X_test)
mse = mean_squared_error(y_test, y_pred)
plt.scatter(X, y, alpha=0.7, label='Actual Data')
plt.plot(X_test, y_pred, color='red', label='Regression Line')
plt.title(f'Linear Regression: MSE = {mse:.2f}')
plt.xlabel('X')
plt.ylabel('y')
plt.legend()
plt.show()
```

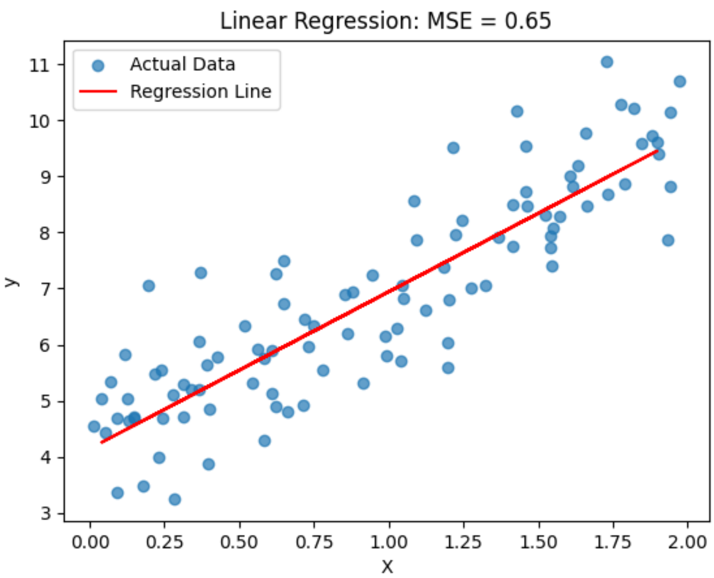

FIG. 1. The simple linear regression model

In this example we generate synthetic data with a linear relationship between X and y, simulating a real-world scenario where data analysis and prediction could be applied. We divide the data into training and test sets to evaluate the performance of the model. We train a simple linear regression model using scikit-learn.

We make predictions on the test set and calculate the mean squared error (MSE) as a measure of how well the model predicts new, unseen data.

Finally, we visualize the data points and the regression line. This example serves as a simplified demonstration of how data analysis and prediction can be implemented using Python. Depending on your specific focus and data, you can choose different algorithms, datasets, and evaluation metrics to further emphasize the importance of these concepts.

B. Simple Linear Regression Model – Mathematical Solution

Simple linear regression assumes a linear relationship between the input variable(X) and the output variable(y), expressed by the equation:

$$y = mx + b \tag{1}$$

where:

- $y$is the predicted value,
- $y$is the input characteristic,
- $m$is the slope of the regression line,
- $b$is the y-intercept.

In the Python code, the 'scikit-learn' library is used to implement this linear regression model. Here are the main steps translated:

```
# Training a linear regression model
model = LinearRegression()
model.fit(X_train, y_train)
```

In this code sequence, the 'fit' method is used to train the model on the training data$(X_{train}\ și\ y_{train})$. After training, the model will be learned to provide optimal values for$m$and$b$.

```
# Obtaining the slope (m) and intercept (b) from the trained model
panta = model.coef_[0][0]
interceptie = model.intercept_[0]
print(f"Panta (m): {panta}")
print(f"Intercepție (b): {interceptie}")
```

Now one can use these values to manually calculate predictions:

```
# Making predictions using the calculated slope and intercept
predicții_manuale = panta * X_test + interceptive
```

In a full mathematical solution, you would also calculate the Mean Squared Error (MSE). MSE is a measure of the mean squared difference between the actual and predicted values given by the formula:

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2 \tag{2}$$

where:

- $n$is the number of data points,
- y_i is the actual value for the data point$i$,
- $\hat{y}_i$ is the predicted value for the data point$i$.

7. CONCLUSIONS

Data analytics and prediction are a powerful tandem that is redefining how organizations approach information and make decisions. In the light of the information provided in this article, we conclude on the profound impact these practices have on the business environment and society in general.

Informatization of Decisions: The use of data analysis and prediction in the decision-making process has transformed the way organizations interpret and use information. From strategic to operational decisions, data and predictions provide the support needed to make informed and well-founded choices.

Operational Efficiency and Resource Optimization: Integrating data analytics and prediction contributes to operational efficiency by identifying opportunities to optimize resources. These practices have the potential to reduce costs, increase productivity and improve the management of organizational resources.

Predicting Hidden Trends and Patterns: The ability of data analysis to identify hidden patterns and trends is crucial to anticipating environmental changes. This ability gives organizations a competitive advantage by adapting to changes before they become apparent through traditional methods.

Ethical Challenges and Data Security: Special attention should be paid to ethical challenges, including data protection, correctness of models and avoidance of bias. Maintaining user trust and upholding ethical standards are essential for the sustainable use of data analytics and prediction.

Future Outlook: The future outlook in data analytics and prediction is encouraging, and technological developments such as artificial intelligence and deep learning will continue to transform the landscape. Smart and ethical implementation of these technologies will determine their direction and impact on society.

In conclusion, data analysis and prediction are not just tools, but engines of innovation and efficiency. A strategic and ethical approach to these practices can shape a future where information becomes a catalyst for progress and wise decision-making, benefiting both organizations and society as a whole.

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THE ROLE OF TECHNOLOGY IN HUMAN RESOURCES MANAGEMENT POST-COVID-19: EMBRACING AI AND AUTOMATION

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Abstract: *The significant transformation of human resource (HR) management in the post-COVID-19 era reflects a paradigm shift, where organizations are increasingly turning to technology to optimize processes and maximize efficiency. This study looks at the integration of artificial intelligence (AI) and automation into HR practices, carefully investigating their impact on recruitment processes, HR management and employee engagement. Comprehensive analysis of how AI is revolutionizing recruitment methodologies and automating routine HR tasks reveals significant changes in how organizations manage their workforce. The research also examines how technology can improve employee engagement, highlighting ways in which AI-based solutions contribute to a more interactive and personalized employment experience.*

A crucial theme is addressed in the paper, the transition to data-driven decision making in HR. The challenges and considerations associated with implementing AI and automation, as well as anticipated future trends, are discussed in detail. Through careful analysis of these issues, the study aims to provide insights into the evolving role of technology in human resource management and its implications for organizations facing the current complexities of the modern workplace.

Keywords: *HR Management, Artificial Intelligence in Recruiting, HR Automation, Employee Engagement, Data-Driven Decision Making, HR Technology, Workforce Planning, HR Analytics, Ethical Considerations, Post-Covid-19 Workplace, Future of Resources human, organizational innovation*

1. INTRODUCTION

The post-COVID-19 era has brought unprecedented changes, affecting not only the way we live and work, but also how organizations approach their most valuable asset: human resources.As the effects of the global health crisis settle in, Human Resources (HR) professionals are facing a new revolution, seeking innovative solutions to navigate the complexities of the post-pandemic world.

The pandemic has accelerated the adoption of technology in all industries, and HR is no exception. As organizations strive to adapt and thrive in this ongoing evolution, the integration of artificial intelligence (AI) and automation is becoming a critical focal point for reshaping HR practices. The aim of this paper is to explore the diverse impact of technology on human resource management, looking at the details of AI and automation adoption and their consequences for recruitment, HR processes and employee engagement.

During this transformative journey, AI's role in revolutionizing recruitment methodologies is becoming a critical component through which organizations identify and attract top talent. At the same time, automating routine HR tasks promises efficiency and cost savings, allowing HR professionals to focus on strategic initiatives.

The use of technology does not just stop at operational improvements, but also extends into the realm of employee engagement, where AI-based solutions are deployed to provide a more interactive and personalized employee experience.

Furthermore, this in-depth exploration moves towards data-driven decision making in HR, highlighting the growing importance of HR analytics in workforce planning, performance management and talent development. With the explosion of data power comes new challenges and considerations, from addressing privacy concerns to ensuring that the human dimension is not lost in technological algorithms.

In this context, the paper not only analyzes the current state of AI and automation in HR, but also projects future trends and innovations that promise to continuously shape the HR landscape. As organizations explore these uncharted territories, understanding the challenges and opportunities brought by integrating technology into HR becomes essential.

Essentially, this paper sets out to decipher the complexities of the post-COVID-19 HR environment, providing insights into how organizations can use AI and automation to foster a more agile, efficient and engaged workforce. By carefully exploring the evolving role of technology in HR, we aim to contribute to the ongoing dialogue about the future of HR management in a world forever changed by recent events in history.

2. THE RISE OF AI IN RECRUITMENT

The transformation of the recruitment landscape has been profound with the advance of artificial intelligence (AI).In the past, the hiring process, characterized by laborious and time-consuming efforts, has been redefined by AI algorithms that bring unmatched efficiency and objectivity to candidate selection.AI-powered recruiting tools analyze large data sets, quickly screen resumes, identify top candidates and predict their potential fit within an organization. This process not only accelerates hiring, but also minimizes human bias, thereby promoting a more inclusive and diverse workforce.[1]

The accuracy of artificial intelligence is not limited to the initial screening phase; machine learning algorithms are continuously improving their capabilities. These algorithms learn from historical hiring data, adapting and evolving to better match candidates based on an organization's specific needs and culture. As organizations strive to build dynamic teams to meet the challenges of a post-pandemic world, AI is becoming a strategic ally in the recruitment process. (Fig.1.) [2]

FIG. 1. Block diagram of the recruitment process with the help of artificial intelligence

However, integrating AI into recruiting is not without its challenges. Ethical considerations such as algorithmic bias and the risk of reinforcing existing inequalities require a careful approach. As organizations increasingly depend on artificial intelligence to shape their workforce, it is critical to strike a delicate balance to ensure that technology supports human decision-making, rather than replacing it. It's a path that requires caution and adaptability as innovations in AI-assisted recruiting continue to redefine the hiring landscape.

3. AUTOMATION IN HR PROCESSES

The automation of routine tasks in the field of Human Resources (HR) is an eloquent manifestation of the transformative capacity of technology. Routine administrative functions such as payroll processing, attendance monitoring and benefits administration are now handled with remarkable efficiency by automated systems. This shift not only frees HR professionals from monotonous and time-consuming tasks, but also gives them the opportunity to focus on strategic initiatives that directly contribute to organizational success. (Fig. 2)

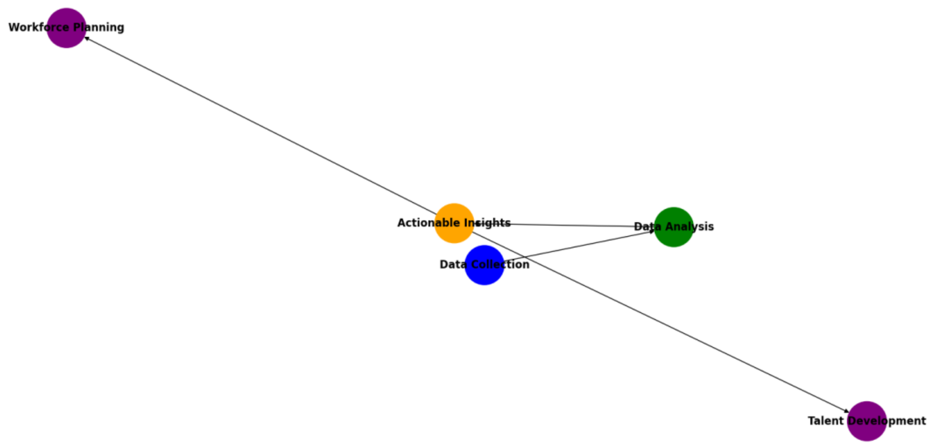

FIG 2. The flow model of data analysis

The benefits of automation in HR go beyond efficiency gains. Accuracy and compliance are significantly improved, thereby reducing the risk of human error and addressing regulatory challenges. In addition, employees benefit from streamlined processes with access to quick answers to HR questions and a smoother onboarding experience [3], [4].

However, as organizations embrace automation, it is crucial to recognize the potential challenges. Anxiety about changing jobs is real, necessitating the need for well-thought-out change management strategies to address employee fears and facilitate a smooth transition. In addition, the intrinsically human aspects of HR, such as empathy and subtle decision-making, must remain central in the context of the rise of automation.

In conclusion, the rise of artificial intelligence in recruitment processes and the automation of HR tasks mark a paradigm shift in the way organizations manage their most valuable asset – human capital. While these technological advances promise increased efficiency and objectivity, they also raise ethical and people-oriented issues that require careful navigation to ensure a harmonious integration of technology into HR.

4. ENHANCING EMPLOYEE ENGAGEMENT WITH TECHNOLOGY

In the contemporary work environment, technology is no longer just a simple tool; it has turned into a catalyst that stimulates employee engagement.AI-based solutions and digital platforms are fundamentally redefining the employee experience by providing personalized and interactive touch points. AI-powered chatbots make a significant contribution to real-time communication, providing instant support for common questions and facilitating employees' access to information in a fluent manner [5].

In addition, the technology facilitates continuous feedback loops and performance monitoring. Through AI analytics, organizations gain deep insights into employee mood, enabling them to take proactive steps to address concerns and improve morale. Virtual collaboration tools further extend the ability to work as a team, connecting remote and in-office employees in a unified digital space [6].

However, the crucial challenge lies in maintaining a balance between technological involvements and maintaining human contact. Achieving this balance ensures that employees not only benefit from the support of technology, but also experience the empathy and genuine understanding that human interaction brings to the workplace context.

5. DATA-DRIVEN DECISION-MAKING IN HR

In the post-COVID-19 era, the importance of data in HR decision-making has evolved significantly. Human resource analytics, driven by data-driven insights, provides strategic insight through which organizations can optimize workforce planning, talent development and performance management. By using data, organizations can identify emerging trends, forecast future requirements, and make informed decisions that lead to the overall success of the organization [7].

In addition, HR data analysis improves objectivity in performance appraisal processes and facilitates the development of targeted training and development programs. The ability to measure the impact of HR initiatives gives organizations the opportunity to optimize their strategies, aligning them more closely with overall business objectives. However, with data-driven decision-making, critical ethical challenges arise. Protecting employee privacy, ensuring data accuracy and addressing algorithmic biases are becoming critical issues. Finding a balance between the efficient exploitation of the power of data and the respect of individual rights becomes imperative for the ethical implementation of analyzes in the field of human resources [8].

6. CHALLENGES AND CONSIDERATIONS

As technology permeates HR and brings with it numerous advantages, it is inevitable that we will also encounter significant challenges. One of these challenges lies in the possible resistance of employees, who may feel that they are being burned out by the rapid changes. In this context, effective change management strategies become essential to communicate the benefits of technological progress, address concerns and facilitate a smooth transition.

In addition, the fear of job relocation is becoming a significant concern, especially with the automation of routine HR tasks. Organizations must actively address this concern by highlighting the collaborative nature between people and technology within the work environment. Upskilling and reskilling programs can be fundamental in empowering employees to adapt to technological developments.

Another crucial consideration is implementing robust cybersecurity measures to protect sensitive HR data. As technology becomes more integrated into HR processes, the risk of data breaches and cyber threats increases. Implementing strict security protocols and ensuring compliance with data protection regulations becomes the necessary imperative.

In conclusion, while bringing technology into HR opens up opportunities for transformation, properly addressing the challenges of employee engagement, data-driven decision making, and overall technology adoption are key to a successful and sustainable integration. Organizations that carefully manage these challenges can create a work environment that is not only technologically advanced, but also oriented toward human needs.

7. FUTURE TRENDS AND INNOVATIONS

Human resource (HR) management is in a stage of preparation for continuous evolution, guided by emerging trends and innovative technologies. As organizations adapt to the dynamic post-COVID-19 landscape, several trends are influencing the direction in which HR practices are evolving. [11],[12]

1. Augmented Reality (AR) and Virtual Reality (VR) in Training:

The integration of AR and VR revolutionizes employee training and development. Immersive learning experiences allow employees to acquire skills in realistic virtual environments, thereby helping to improve information retention and engagement in the learning process.

2. Predictive analytics for retention:

The predictive analytics approach is becoming increasingly sophisticated, enabling organizations to anticipate staff turnover and implement preventative measures to retain top talent. By analyzing historical data and identifying patterns, the HR department can adopt customized retention strategies.

3. Personalization based on artificial intelligence:

AI technology is used to further personalize the employee experience. From personalized learning paths to individually tailored wellness programs, AI algorithms analyze individual preferences and behaviors to deliver personalized HR solutions.

4. Blockchain for HR data security:

Blockchain technology is becoming increasingly relevant in the field of HR due to its potential to improve data security. Blockchain's decentralized and tamper-proof system can ensure the privacy and integrity of sensitive HR data.

5. Emphasis on employee well-being:

There is a growing focus on employee well-being, with organizations recognizing the importance of the link between employee health, productivity and organizational success. Wellness programs, including mental health support, work-life balance initiatives and holistic wellness strategies, will take center stage.

CONCLUSION

The conclusion highlights that the post-COVID-19 era has ushered human resource (HR) management into a new phase, characterized by the strategic integration of technology and the adoption of innovative practices. The rise of artificial intelligence (AI) in the recruitment process, automation of HR tasks, increased employee engagement through technology and data-driven decision making are significant milestones in the transformation of HR.

Looking ahead, a human resource management trajectory shaped by multiple trends and innovations is taking shape. Augmented and virtual reality will redefine training methods, predictive analytics will give organizations the ability to proactively manage employee retention, and AI-based personalization will tailor the HR experience to individual needs.

While adapting to these changes, organizations must be alert to the challenges associated with technology adoption, including ethical considerations and potential employee resistance.

Finding a balance between the human element and technological efficiency will be key to building workplaces that are not only technologically advanced, but also compassionate and people-centered.

At its core, the future of HR is shaping up as a dynamic interplay between cutting-edge technologies, human-centered practices, and a commitment to fostering an agile, engaged, and resilient workforce. By carefully embracing these changes, organizations can position themselves at the forefront of the ever-evolving HR landscape, ready to address challenges and exploit future opportunities.

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DESIGN, AERODYNAMIC ANALYSIS AND MANUFACTURE OF A FLYING WING

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Abstract: *This paper has demonstrated the feasibility of manufacturing a flying wing by performing the following steps: making a sketch of the model, establishing the preliminary design and sizing of the model, computer-aided designing using specific software systems, aerodynamic analysis of flight performance, manufacturing and assembling the components, and finally testing the motor and control elements. The wing model has a mass of 750 grams, a maximum speed of about 50 km/h and a range of 17 minutes. The wing model has been designed to accommodate a small video camera that can transmit images in real time. The wing can perform multiple missions: aerial surveillance of certain areas of interest or search and rescue missions in hard-to-reach areas.*

Keywords: *design, flying wing, CFD analysis, finite element analysis, manufacturing*

1. INTRODUCTION

UAV (Unmanned Aerial Vehicle) is an aircraft that can fly without the need for a pilot on board and is autonomously controlled using a remote control [1]. In recent years, UAVs have experienced tremendous development and have gained rapid growth in popularity worldwide. Nowadays, UAVs are widely used in various fields such as [2,3]: military and defence applications, reconnaissance, surveillance and security enhancement, agriculture, fire detection, search and rescue. The sales of the UAVs are expected to grow, especially in the current military situation.

Flying wings can be manufactured from several types of materials (composite, wood, plastic), as each material has both advantages and disadvantages [4]. Typically, flying wings made of polystyrene have a lower mass compared to those made of balsa wood or 3D printed [5]. The foam from which these types of aircraft are made, has a lower density, which implicitly means lower mass. The foam is less strong, but the structural behaviour can be improved by using reinforcing elements, such as inserting carbon rods into its structure [6,7]. Balsa wood is used in the manufacturing of wings, but with the advent of more modern (composite) materials, its use has decreased. Balsa wood has a low weight, rather high strength, and high flexibility [8].

3D printed wings [9] can be manufactured with varying degrees of strength, flexibility and weight depending on the type of material and thickness of the printed parts. The disadvantage of 3D printed wings is that they require a digital model design and the use of a 3D printer, which implies higher costs and more advanced technical knowledge. However, by using a 3D printer, complex shaped parts can be produced as required, whereas polystyrene and balsa wood have less capability in this respect.

Based on various comparisons, it was decided for this paper to make a flying wing out of depron (expanded polystyrene) because it has similar properties to foam.

The use of this material allows the final aeronautical product to have a reduced mass, which will have a positive influence on flight performance, especially aerodynamics and range. At the same time, depron can be easily cut and shaped to obtain the desired aerodynamic profile, can be assembled quickly, and requires the shortest manufacturing time compared to the other materials analysed. Depron is also an easily available material and has a low cost [10]. This material has high insulation properties, this feature being useful when the wing flies at varying temperatures, thermal insulation helps to secure the electronic parts [10].

Depron can also help to create a solid structure. Significant progress has been made in the aerodynamic study of these aircraft, leading to high performance, profiles that provide minimal drag, high controllability, and high stability. Today, the manufacture of flying wings is increasingly based on composite materials because they offer high strength and low mass [11]. With the emergence of 3D printing technologies, considerable advantages have emerged that have allowed precise and relatively fast manufacturing having high quality and strength [12].

Flying wings are equipped with advanced electronic systems that help in conducting missions, such as cameras, sensors, advanced navigation systems. There has been a dramatic evolution in flight autonomy, the first wing models built had low autonomy (a few minutes of flight time), but thanks to the evolution of batteries and optimal aerodynamic profiles, flights lasting several hours have been possible. In conclusion, the evolution of flying wings is characterised by continuous innovations in the materials used, with increasing efficiency, so that they can be used in a wide range of missions in different fields.

2. DESIGN OF THE FLYING WING

The requirements to be met by the flying wing model were to design an aircraft with a short manufacturing time, medium range; to reach a flying height of 120 metres; to create as little drag as possible; to be manufactured at the lowest possible cost. At this stage, the wing design process (Fig.1) was developed using the CATIA V5 software system, considering the conceptual model and the established dimensions. The airfoil (NACA 2412) was imported into the CATIA V5 software from the Airfoil Tools website. Ribs and ailerons have been added as well as winglets. Analyses of other types of flying wings showed that their aerodynamic efficiency would increase if winglet systems were added.

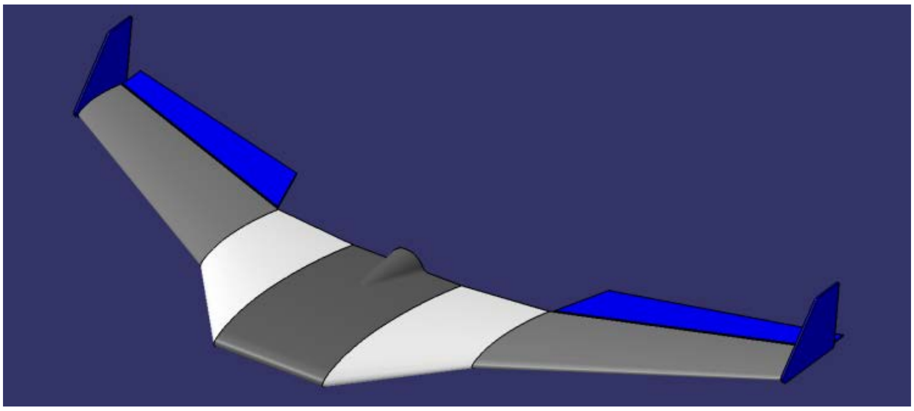


FIG. 1. Digital model of the wing

The flight performance analysis was carried out using the "eCalc.ch" website, which provides a wide range of tools to assess the performance of the radio-controlled aircraft. The most important information calculated are flight time (estimated at maximum 17 minutes), maximum speed of 50 km/h, rate of climb of about 4 m/s and stall speed of 22 km/h. The wing parameters entered into the computer for performance estimation were wing mass 750 grams; number of motors 1; wingspan 1300 mm; wing area 36.54 dm^2; LiPo 2500 mAh battery; speed controller 40 A; SunnySky X2216 motor; GEMFAN 8 x 4 inch propeller.

3. AERODYNAMIC ANALYSIS OF THE FLYING WING

For the analysis, the XFLR5 software system was used to calculate the performance of the flying wing. The NACA 2412 airfoil (Fig.2) was imported from the Airfoil Tools website into the XFLR5 software system in order to analyse the wing.

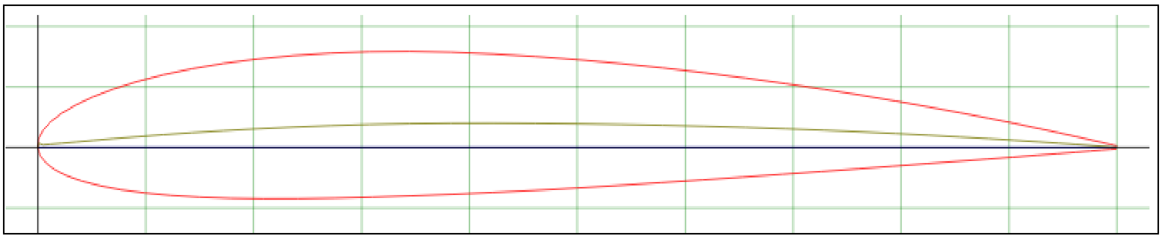


FIG. 2. NACA 2412 airfoil

The wing modelling steps: the flying wing was modelled in the XFLR5 software system (Fig. 3), with real configurations, 1300 mm wingspan; 750 g weight was set; winglet surfaces were modelled in each plane, the profile used was NACA 2412. Aerodynamic analysis was carried out for a speed of 10 m/s, and angles of attack varied from -4° to 7°.

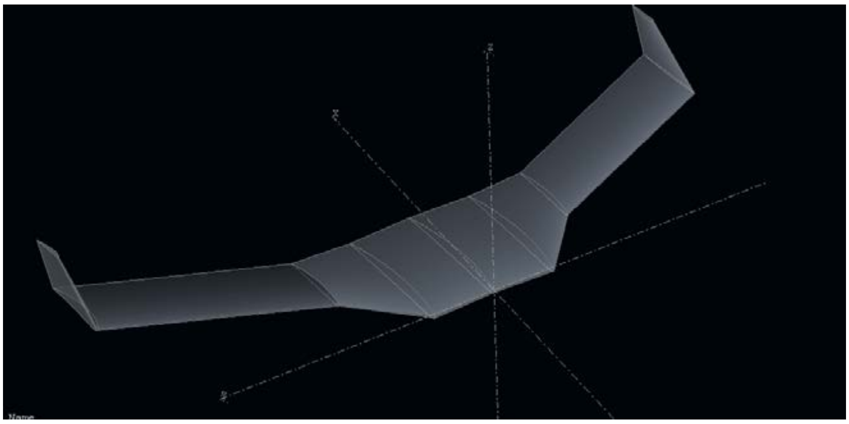
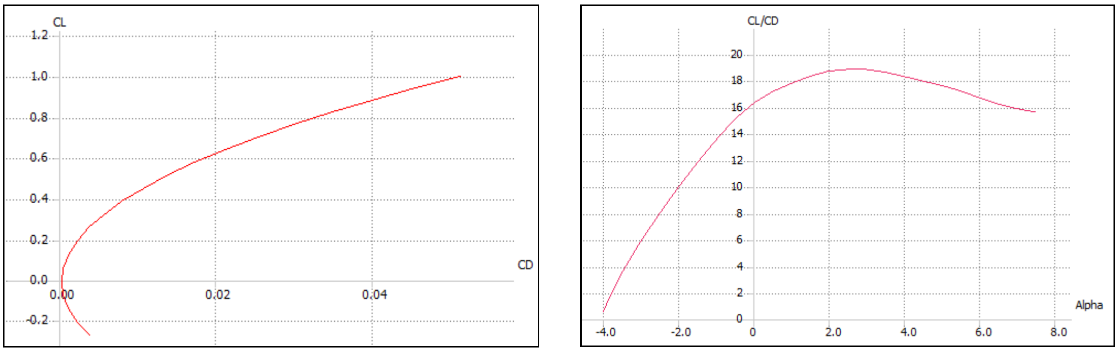


FIG. 3. Digital wing model designed in XFLR5 software system

The polar curve (Fig.4a) shows the relationship between the lift coefficient and the drag coefficient. This graph is used to analyse the aerodynamic performance of the wing.

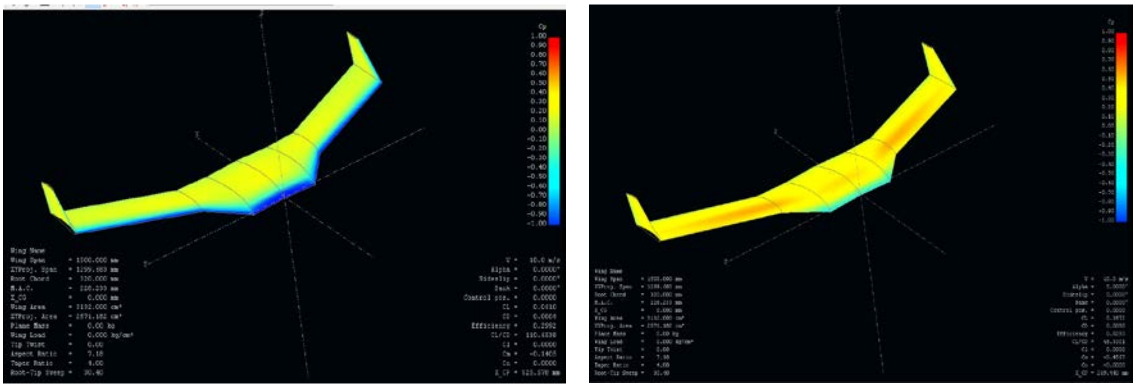
The wing fineness as a function of the angle of attack (Fig.4b) refers to the ratio between the lift coefficient (CL_{max}=1) and the drag coefficient (CD_{max}=0.05) of the wing at a given angle of attack. The fineness (lift-to-drag ratio) is an aerodynamic characteristic that influences the performance of any aircraft.



(a) (b)

FIG. 4. Aerodynamic performance of the wing (a) Distribution of lift coefficient as a function of drag coefficient (b) Wing fineness as a function of the angle of attack.

The distribution of the pressure coefficient on the wing as a function of the angle of attack indicates the simulation of the pressure of the airfoils acting on the wing. This pressure influences the lift and the drag and varies along the wing. At low angles of attack the pressure coefficient distribution is characterised by higher values on the upper surface and lower values on the lower surface (Fig.5a). As the angle of attack changes (Fig.5b), the pressure coefficient distribution changes, as can be seen in Fig.5, when the angle of attack increases the pressure coefficient tends to increase as well, but this happens up to a certain limit, called the airfoil separation point or stall speed.



(a) (b)

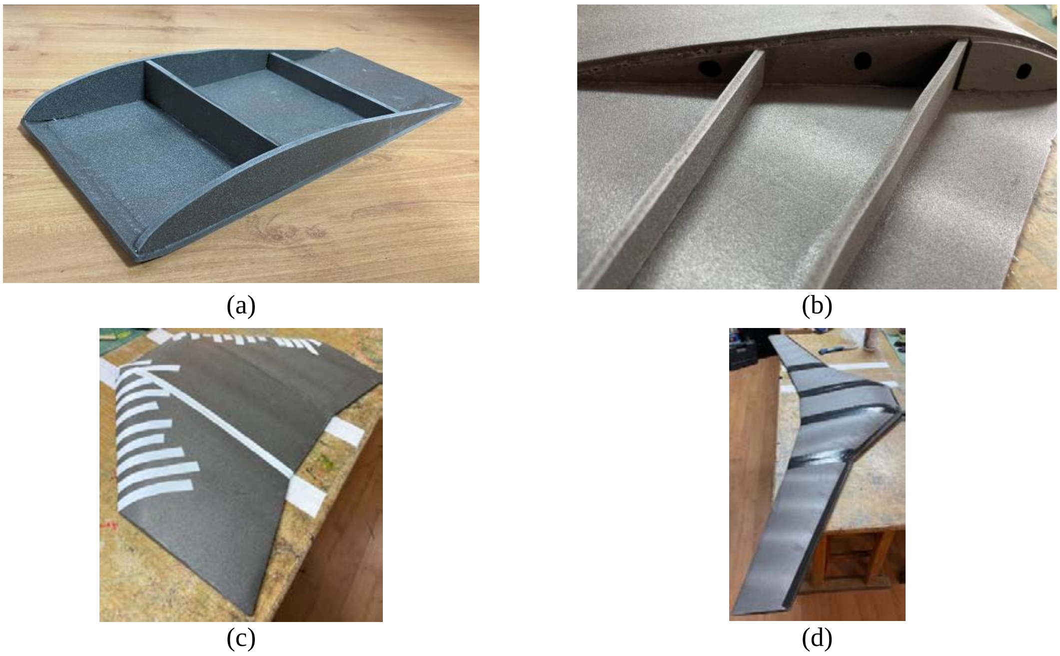
FIG. 5. Aerodynamic analysis of the wing (a) Pressure coefficient distribution at 0° angle of attack (b) Pressure coefficient distribution at 5° angle of attack

4. MANUFACTURING AND ASSEMBLY OF THE WING COMPONENTS

The primary need of UAV designers and operators is to manufacture an aeronautical product with low mass and high strength. With this in mind, depron was chosen as the main material for the wing manufacturing. The assembly of the wing parts was a complex process involving several steps and bonding methods (Fig.6a). An adhesive which is compatible with the depron is required, as most adhesives will melt these boards.

The role of the spars (Fig.6b) is to take up the loads and transfer them evenly so that no significant deformation occurs in flight. A rib was placed at the junction (Fig.6c) between the two wing planes to increase the strength of the area. The next step was to add the control surfaces, winglets, electronics, and motor mount.

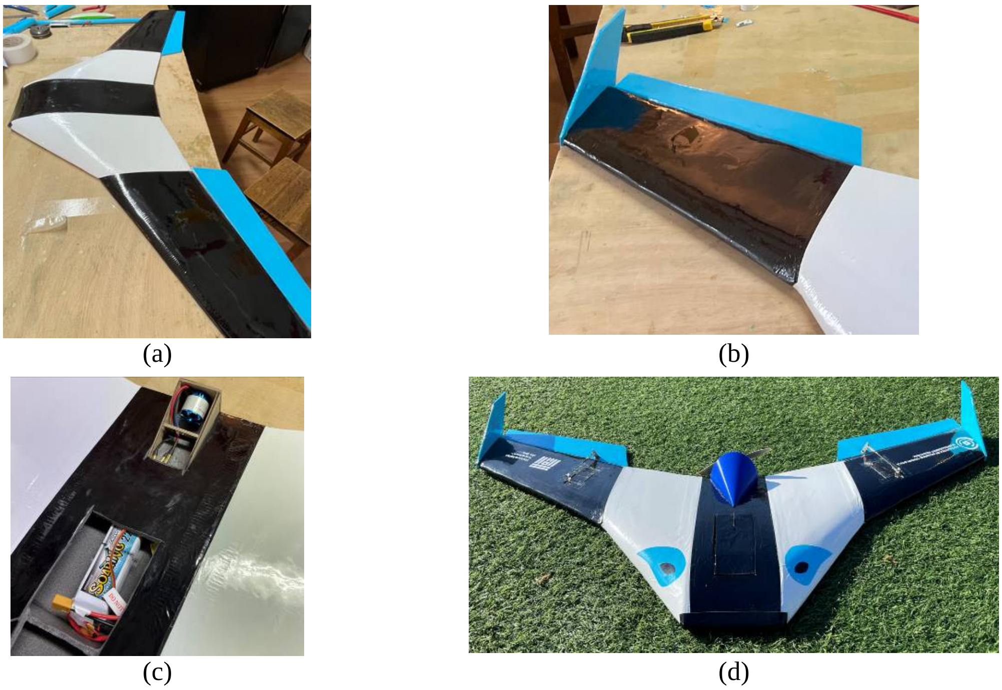
Fig.6d shows how the adhesive tape with fibreglass inserts was applied to the leading edge and all areas where jointing was carried out.



(a) (b) (c) (d)

FIG. 6. Main steps of wing assembly (a) internal structure (b) positioning the spars (c) assembly of the central structure (d) application of adhesive tape to the outer surface

Next, as may be seen, the blue thermal adhesive tape was applied to the control surfaces and attached to the wing structure by means of a transparent adhesive strip (Fig.7a). The winglet surfaces were then added on the right and left planes (Fig.7b). The winglet is intended to improve the aerodynamic efficiency of the wing by reducing the drag induced at the wingtip.



(a) (b) (c) (d)

FIG. 7. Final assembly of the wing (a) Adding the control surfaces (b) Fitting the winglets (c) Positioning the LiPo battery and brushless motor (d) Wing ready for flight.

In the next stage of manufacturing, the motor mount was fitted to the wing, using the bonding process with the same adhesive that was used to bond the depron (Fig.7c). As shown in Fig.7d, the motor cone (3D printed) was attached to the wing by bonding, which covers the motor, provides protection, and helps reduce drag. The completed wing ready for flight can be seen in Fig.7d. The manufacturing process took aproximately 35 hours and required a relatively simple set of tools and a single type of adhesive.

5. CONCLUSIONS

This study demonstrated the feasibility of manufacturing a flying wing starting from the preliminary design stage and ending with ground testing of the model. An important aspect to consider is the quality of the manufacturing of the wing, the low cost at which it was made, and the relatively short time in which the wing was manufactured. The final weight of the wing, equipped for flight, was about 750 grams, which is an advantage compared to the 1300 mm wingspan. The maximum speed the wing can reach is about 50 km/h. The estimated flight time is 17 minutes, but this may be influenced by the capacity of the battery and its quality. The speed at which the critical stall speed is reached is about 22 km/h and the maximum height to which the wing can lift is up to 500 metres. The flying wing can be used for reconnaissance, surveillance, search and rescue missions with the use of a camera.

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MULTICRITERIA ANALYSIS OF PARACHUTES USED BY SPECIAL OPERATIONS FORCES

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Abstract: *Special operations forces are well-known for their expertise in rapid tactical interventions, and the use of parachutes plays a crucial role in their arsenal. These elite units rely heavily on parachutes to conduct swift and clandestine insertions into inaccessible or challenging terrain, allowing them to catch adversaries off guard and execute critical missions with precision and efficiency.*

To establish a ranking of parachutes utilized by special operations forces using multicriteria analysis, it is imperative to delineate evaluation criteria and assign appropriate weights based on their relative significance. Each parachute undergoes assessment according to these criteria, receiving scores commensurate with its performance. Subsequently, total scores are tabulated for each parachute, predicated on the weights allotted to each criterion. The resultant ranking affords a lucid perspective on the optimal options, aiding special forces in making well-informed and strategic decisions concerning the equipment utilized in their operations.

Keywords: *multicriteria analysis, parachute, special operations forces*

1. INTRODUCTION

Special forces represent the pinnacle of military capabilities, equipped with state-of-the-art skills and technologies to carry out missions in the most challenging and hazardous environments. The use of parachutes constitutes one of the most essential components of their arsenal, enabling them to execute operations rapidly and without detection. These elite units are trained to utilize parachutes in a variety of scenarios, including infiltrations into steep mountain terrain or deep jungle environments where ground access would be impossible or extremely perilous. The ability to land precisely and swiftly maneuver post-descent provides them with a significant strategic advantage, allowing them to surprise the enemy and accomplish objectives efficiently. Additionally, parachuting plays a crucial role in emergency evacuations or personnel recovery operations in conflict zones, providing special forces with the capability to act swiftly and decisively in critical situations. Thus, parachuting is not merely a technique but a vital element in the arsenal of special forces, significantly contributing to the success and effectiveness of their missions in the most extreme and unpredictable circumstances. [1]

The article outlines the complex and meticulous process of compiling a ranking of parachutes used by special forces through multicriteria analysis. The authors emphasize the importance of establishing evaluation criteria such as reliability, landing accuracy, versatility, weight, and costs. By employing a systematic and objective approach, each parachute undergoes assessment based on these criteria, receiving corresponding scores.

Following the assignment of weights and calculation of total scores, a ranking is formulated that reflects the best options according to the specific needs and requirements of the special forces. The article underscores the essential role of multicriteria analysis in making informed and strategic decisions, contributing to optimizing operational performance and resource utilization in special operations.

Therefore, within the multicriteria analysis, we will consider the following items: wing-type parachutes used for infiltration, both through the HAHO (High Altitude High Opening) and HALO (High Altitude Low Opening) methods, as well as round parachutes used for infiltration from low to very low altitudes.

2. THE CONCEPT OF THE STUDY OF A MULTICRITERIA ANALYSIS

Multicriteria analysis describes a structured approach used to determine overall preferences from multiple alternative options, which aim to achieve a set of specific objectives. Within such an analysis, the pursued objectives are specified, and the relevant indicators are identified. [2]

Therefore, the analysis proves useful for a wide variety of applications, ranging from the most mundane (such as purchasing a car) to simulating more complex public procurement processes, such as acquiring a multi-role aircraft or modernizing the fleet of attack helicopters of the Romanian Air Force.

The purpose of this method is to achieve a comparative evaluation of heterogeneous measures or alternative projects. Therefore, the actual measurement process and the indicators used in multicriteria analysis should not be monetarily based, but they still rely on quantitative analysis (through scoring, ranking, and weighting) of a range of qualitative categories and criteria. Given that this method provides techniques for making comparisons and hierarchies of different outcomes, utilizing a wide variety of indicators, it can be concluded that it is particularly applied in cases where addressing the problem through a single criterion is insufficient. The aim of this analytical tool is to structure and combine different evaluations that need to be taken into account in the decision-making process, in cases where decision-making involves multiple alternatives, and the treatment applied to each of these largely conditions the final decision.[3]

It is important to note that multicriteria analysis is used to highlight subjective opinions and the reasoning of stakeholders regarding each problem presented. It is often used to establish priority structures, synthesize expressed opinions, analyze conflicting situations, and formulate recommendations or provide operational advice.

In multicriteria analysis, the criterion represents the unit of measurement according to which options are compared and evaluated to determine the extent to which they contribute to achieving the proposed objective. It is crucial that each criterion measures a relevant aspect and does not depend on another criterion. [4]

In the example provided below, the acquisition of a helicopter for the modernization of the Romanian Air Force fleet is being considered. The selection of a helicopter model is the subject of a Multicriteria Analysis. The information in Table 1 presents the description of 5 criteria, providing: the symbol and name of the criteria, the indicator used for quantifying the criteria, the value ranges of the criteria, and the effect pursued for each criterion.

Table 1.The criteria and their respective value ranges

Criteria		Indicator	Value Ranges	Effect Maximum(+)/ Minimum(-)
C_1	Maximum Takeoff Weight	Kilograms	$[x_1...x_n]$	-
C_2	Performance	Engine Power(horsepower)	$[x_1...x_n]$	+
C_3	Rate of Climb	Feet/minute	$[x_1...x_n]$	-
C_4	Maximum Speed	Knots	$[x_1...x_n]$	+
C_5	Range	Kilometers	$[x_1...x_n]$	+

A standard tool of multicriteria analysis is the performance matrix (also known as the consequence table or decision matrix). Each row of this matrix describes an option, and each column shows the performance of the options based on each criterion. Performance evaluations are often numerical but can also be expressed through scoring, graphical representation, or color coding. The table below presents the general form of a performance matrix for options and criteria. The scores in the matrix cells are denoted as a_{ij} and represent the value associated with option i for criterion j.

Table 2.The performance matrix

Criterion / Options	C_1	C_2	$...C_j...$	C_n
A_1	$a11$	$a12$	...	a_{1n}
A_2	$a21$	$a11$	...	$a11$
$...A_i...$	...	...	a_{ij}	...
A_m	$am1$	$am2$	...	amn

In the basic form of multicriteria analysis, this performance matrix can represent the final product of the analysis. In the techniques of multicriteria analysis, the information from the basic matrix is transposed into coherent numerical values. Normally, numerical analysis of a performance matrix is applied in two different stages:

Firstly, scoring involves assigning a numeric score on the preference level scale for each option of the criteria, based on the anticipated consequences for each option. Options that are preferred receive a higher score on the preference scale, while less preferred options receive a lower score. In the proposed study, the scale used will range from 1 to 3, where 1 represents the least preferred option, while 3 is associated with the most preferred option. Ultimately, all options considered in the study will fall between 1 and 3.

The second step is weighting, which involves assigning numerical weights to define, for each criterion individually, the estimates of oscillations between the lower and upper limits of the chosen scale. At this stage, each decision criterion is assigned a "value" or "weight," and the decision criteria acquire a relative weight compared to each other - weighting the decision factors is necessary if we want to combine them in the end.

For the numerical example used so far, let's consider that a group of experts has analyzed the selection criteria for the proposed alternatives and consulted with the main stakeholders. Regarding the consideration of weights, the interval [1,5] is taken into account, where the value 1 represents the least important criterion, while the value 5 represents the most important criterion. They have decided that helicopter performance is the most important criterion, and its weight should be 4, while rate of climb and maximum takeoff weight are the least important criteria, with a weight of 1, whereas maximum speed and range have moderate relevance and a weight of 3.

These results are presented in Table 3.

Table 3.The estimated weights directly

Criterion	C_1	C_2	C_3	C_4	C_5
Weight	1	4	1	3	3

In the final stage of multicriteria analysis, mathematical calculations are used to suggest the preferred option, representing the variant that best meets the needs and standards for the acquisition of helicopters for the modernization of the Romanian Air Force fleet.

It is important to note that, in developing the mathematical calculations, column-wise multiplication is performed, element by element, followed by adding up the values. The resulting sum represents the value of the respective option, with the maximum value indicating the winning option.

$$R = \max(\Sigma pc * p) \quad (1)$$

where:
R=the preferred option
Σ= sum
pc= criterion weight
**= multiplication*
p= score

3. MULTICRITERIA ANALYSIS OF PARACHUTE TYPES

3.1. Multicriteria analysis of wing-type parachutes used by special operations forces

To begin with, we will establish the wing-type parachutes used by special operations forces:

Table 4. The wing-type parachutes

The wing-type parachutes	Country
JANUS 300 [5]	Spain
ARZ G9 [6]	France
AS-33 INTRUDER [7]	UK
MC-4 [8]	USA
ARBALET-2 [9]	Russia

Once we have established the wing-type parachutes used by special operations forces, we will initiate the process of multicriteria analysis. To begin with, we will determine the items we consider viable in establishing the final ranking. From my perspective, the most important characteristics to be considered, given the purpose of these parachutes, are: weight, maximum load capacity, aerodynamic efficiency, surface area, and finally, maximum opening altitude.

For this step, I will introduce the items in the table below, along with the indicators and numerical ranges corresponding to each criterion:

Table5. The criteria and value ranges

Criterion		Indicator	Value ranges
C1	Weight	Kilograms	19-29
C2	Maximum Load	Kilograms	159-205
C3	Aerodynamic Efficiency	-	2,5-4:1
C4	Surface Area	Square Meters	29-37
C5	Maximum Opening Altitude	Meters	4500-12000

Once the criteria, their indicators, and their respective value ranges are established, I will create the performance matrix. The rows will represent the criteria, while the columns will represent the wing-type parachute alternatives.

Table 6.The performance matrix

Criteria Alternatives	Weight	Maximum Load	Aerodynamic Efficiency	Surface Area	Maximum Opening Altitude
JANUS 300 [10]	25	160	3:1	29	8000
ARZ G9 [11]	24	160	2,8:1	35,7	10000
AS-33 INTRUDER [12]	29	205	4:1	37	12000
MC-4 [13]	25	180	3:1	35	10000
ARBALET-2 [14]	19	159	2,5:1	34	12000

The next step involves assigning a scoring range to each criterion considered in the performance matrix, for the purpose of normalizing the matrix and facilitating calculations. As mentioned in subsection 3.1.1., the scoring is in the range of values [1,3], where 1 represents the least preferred option, 2 represents the average option, while 3 is associated with the most preferred option.

Table7. The score of each wing-type parachute

Criteria Alternatives	Weight	Maximum Load	Aerodynamic Efficiency	Surface Area	Maximum Opening Altitude
JANUS 300	2	1	2	3	1
ARZ G9	2	1	1	2	2
AS-33 INTRUDER	1	3	3	1	3
MC-4	2	2	2	2	2
ARBALET-2	3	1	1	2	3

Once the scores are established, we need to assign a weight to each criterion mentioned up to this point in the multicriteria analysis. As stated in subsection 3.1.1, in the explanation of this analysis method, the weights are assigned between the values [1,5], where the values represent: 1 - least important, 2 - somewhat important, 3 - moderate, 4 - important, and finally, 5 - most important. Thus, we create the weight matrix as follows.

Table 8. Directly estimated weights

Weight	Maximum Load	Aerodynamic Efficiency	Surface Area	Maximum Opening Altitude
2	4	5	1	3

The final step of the wing-type parachute analysis involves solving the mathematical calculations using the formula presented and subsequently determining the final ranking. Following the mathematical calculations, the following values have been obtained:

Table 9. Scores of the wing-type parachutes

Alternatives	Score
JANUS 300	***24***
ARZ G9	***21***
AS-33 INTRUDER	***39***
MC-4	***30***
ARBALET-2	***26***

Once we have obtained the numerical values, we compile the final ranking as follows:

Table 10. Final Ranking

Position obtained	Final Ranking
1	AS-33 INTRUDER
2	MC-4
3	ARBALET-2
4	JANUS 300
5	ARZ G9

FIG 1. The wing-type parachutes (1-AS-33 INTRUDER [15], 2- MC-4 [16], 3 - ARBALET-2 [17], 4 - JANUS 300 [18], 5- ARZ G9 [19])

3.2. Multicriteria Analysis of Round-Type Parachutes Used by Special Operations Forces

To begin with, we will establish the round-type parachutes used by special operations forces:

Table 11. Round-Type Parachutes

Round-Type Parachute	Country
CIMSA TP-2Z [20]	Spain
TAP 696-26 [21]	France
GQ 8M-LLP [22]	UK
MC-6 [23]	USA
D10 [24]	Russia

Once we have established the round-type parachutes used by special operations forces, we will initiate the process of multicriteria analysis. To begin with, we will determine the items we consider viable in establishing the final ranking. From our perspective, the most important characteristics to be considered, given the purpose of these parachutes, are: weight, maximum load capacity, vertical speed, surface area, and finally, minimum opening altitude.

For this step, I will introduce the items in the table below, along with the indicators and numerical ranges corresponding to each criterion:

Table 12. The criteria and value ranges

Criterion		Indicator	Value ranges
C1	Weight	Kilograms	13-17,5
C2	Maximum Load	Kilograms	140-181
C3	Vertical Speed	Meters per second	5-6
C4	Surface Area	Square Meters	71-100
C5	Minimum Opening Altitude	Meters	76-200

Once the criteria, their indicators, and their respective value ranges are established, I will create the performance matrix. The rows will represent the criteria, while the columns will represent the alternatives of round-type parachutes.

Table 13. The performance matrix

Criteria Alternatives	Weight	Maximum Load	Vertical Speed	Surface Area	Minimum Opening Altitude
CIMSA TP-2Z [25]	14	160	5,5	79	125
TAP 696-26 [26]	13,5	160	5,5	74	150
GQ 8M-LLP [27]	13,6	160	6	75	76
MC-6 [28]	13	181	5	71	152
D10	17,5	140	5	100	200

The next step involves assigning a scoring range to each criterion considered in the performance matrix, in order to normalize the matrix and facilitate calculations. As mentioned in subsection 3.1.1., the scoring is in the range of values [1,3], where 1 represents the least preferred option, 2 represents the average option, while 3 is associated with the most preferred option.

Table 14. The score of each round-type parachute

Criteria Alternatives	Weight	Maximum Load	Vertical Speed	Surface Area	Minimum Opening Altitude
CIMSA TP-2Z	2	2	2	2	2
TAP 696-26	2	2	2	2	2
GQ 8M-LLP	2	2	1	2	3
MC-6	3	3	3	3	2
D10	1	1	3	1	1

Once the scores are established, we need to assign a weight to each criterion mentioned up to this point in the multicriteria analysis. As stated in subsection 3.1.1., in the explanation of this analysis method, the weights are assigned between the values [1,5], where the values represent: 1 - least important, 2 - somewhat important, 3 - moderate, 4 - important, and finally, 5 - most important. Thus, we create the weight matrix as follows.

Table 15. Directly estimated weights

Weight	Maximum Load	Vertical Speed	Surface Area	Minimum Opening Altitude
2	4	5	1	3

The final step of the round-type parachute analysis involves solving the mathematical calculations using the formula presented and subsequently determining the final ranking. Following the mathematical calculations, the following values have been obtained:

Table 16. Scores of the round-type parachutes

Alternatives	Score
CIMSA TP-2Z	30
TAP 696-26	30
GQ 8M-LLP	26
MC-6	42
D10	25

Once we have obtained the numerical values, we compile the final ranking as follows:

Table 17. Final Ranking

Position obtained	Final Ranking
1	MC-6
2	CIMSA TP-2Z
3	TAP 696-26
4	GQ 8M-LLP
5	D10

FIG. 2. The round-type parachutes (1-MC-6, 2-GQ 8M-LLP, 3-D10, 4-TAP 696-26, 5- CIMSA TP-2Z)

CONCLUSIONS

This multicriteria analysis provides a detailed perspective on various aspects of wing-type parachutes used by special forces, highlighting the importance of each criterion and how they influence the operationality and effectiveness of these vital equipment in different usage scenarios. Proper weighting of the criteria is crucial for obtaining a balanced and relevant assessment of the available options. For instance, weight and load capacity are essential for the mobility and flexibility of special operations forces in challenging terrains or during long-duration missions, while aerodynamic finesse and vertical speed can directly impact the precision and control of landing, being vital in high-risk situations or urban areas. Surface area and minimum opening altitude also play a crucial role in the range and adaptability of parachutes in different terrain and operational conditions. Therefore, it is evident that a holistic and balanced approach in evaluating these criteria is essential for the selection and optimal use of parachutes by special forces.Multicriteria analysis provides significant benefits in the decision-making process, offering a comprehensive and objective perspective on the available options.

These conclusions help substantiate strategic decisions regarding the acquisition, modernization, and utilization of parachutes in special operations, contributing to improving operational capability and increasing the efficiency of special forces in their mission contexts.

The article provides a detailed and well-structured presentation of the multicriteria analysis process for wing-type parachutes used by special forces. Starting from identifying relevant criteria and their value ranges to developing the performance matrix and assigning weights, the analysis is presented coherently and accessibly.

The importance of each criterion in the context of special operations is clarified, and the relevance of each step of the analysis process is argued. The article serves as a valuable starting point in understanding multicriteria analysis of both wing-type and round parachutes, yet there is room for improvement in terms of methodological clarity and detailed discussion of limitations and subjective aspects of the analysis process.

Looking ahead, it is essential to continue developing and refining our multicriteria analysis methods, especially regarding the evaluation and prioritization of criteria based on the specific needs and requirements of special forces. We plan to expand our research to include a broader range of parachutes, thus obtaining a more comprehensive understanding of available options and their potential impact on operational performance. Ultimately, we aim for the results of this research to contribute to enhancing the operational capabilities of special forces and providing support for informed and strategic decision-making regarding the equipment and technologies used in their critical operations.

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DEVELOPMENT AND IMPLEMENTATION OF INTELLIGENT ENERGY MANAGEMENT SYSTEMS AND EDUCATION PROGRAMS TO OPTIMIZE RESOURCE CONSUMPTION ON UNIVERSITY CAMPUSES

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Abstract: *The article presents a systematic step-by-step approach to optimizing resource consumption on college campuses through the implementation of intelligent energy management systems (IEMSs) and energy efficiency education programs (3EP). The implementation methodology is discussed, highlighting the stages of evaluation, selection of IEMS, as well as their benefits, functionalities and challenges. We have also highlighted the types, benefits and made a number of recommendations aimed at providing energy resilience to university campuses. The major benefits of this approach are highlighted, including cost reduction, improved energy efficiency, increased awareness and responsibility of students and staff and building a modern and high-performing learning environment.*

Keywords: *intelligent energy management systems, SMART, resource consumption optimization, university campus, education, energy efficiency, best practices, combating climate change, resilience, sustainability.*

1. INTRODUCTION

The world faces a number of major challenges related to climate change and energy security. Population growth, industrialisation and dependence on fossil fuels have led to a significant increase in energy consumption and greenhouse gas emissions, which have a negative impact on the environment [1]. Energy efficiency has become a global priority and is key to reducing CO_2 emissions, fighting climate change and ensuring a sustainable future. Universities, as higher education institutions and research centres, have an important role to play in promoting sustainable practices and energy efficiency.

According to the Agency for Energy Efficiency and Environmental Protection, statistical data on the carbon footprint [2] for people in Romania is 3.85 tons, for the European Union it is 6.8 tons, worldwide we have an average of 4.79 tons. The target for 2050 wants the carbon footprint to be zero.

This paper aims to present an **intelligent energy management system** and **education programs** dedicated to optimizing resource consumption on university campuses. The successful implementation of these solutions will help to significantly reduce energy consumption, CO_2 emissions and operational costs, while increasing energy awareness and student and staff responsibility.

According to the Agency for Energy Efficiency and Environmental Protection (Figure 1), statistical data on the carbon footprint [2] for people in Romania is 3.85 tons, for the European Union it is 6.8 tons, worldwide we have an average of 4.79 tons. The target for 2050 wants the carbon footprint to be zero.

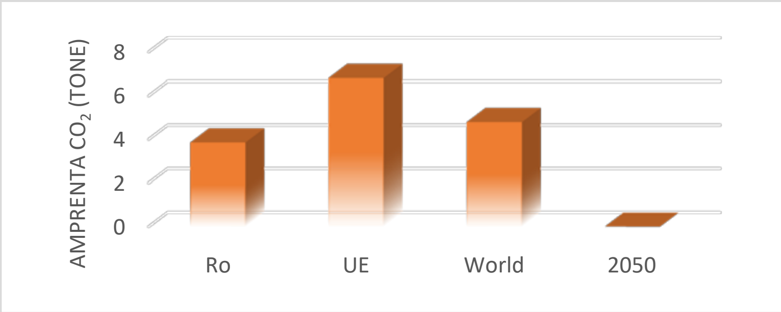

FIG. 1 Statistical data on the carbon footprint for people in Romania, EU, worldwide and target for 2050

2. INTELLIGENT ENERGY MANAGEMENT SYSTEMS (IEMSs)

Intelligent Energy Management Systems (IEMSs) are advanced solutions that use a combination of sensors, actuators, software and intelligent algorithms to optimize energy consumption on university campuses. For a better understanding of them, we will present the benefits, functionalities as well as the challenges of implementing and developing IEMS.

1.1.Benefits of IEMS

The implementation of an IEMS on university campuses can generate a number of significant benefits, with economic, environmental and social impact. Thus, we will point out the most important of these. **Significant reduction of energy consumption and costs** by values between 10-20%, generating significant financial savings. **Increasing energy efficiency** achieved by optimising energy consumption reduces the CO_2 footprint and contributes to combating climate change. **Improving comfort and quality of life** [3] results from the fact that an intelligent energy management system can contribute to improving thermal comfort and quality of life on campus, with staff benefiting from optimal living conditions.

A very important benefit, taking into account the fact that the staff involved is in the hundreds, even thousands of individuals, students, staff and auxiliary staff alike, is **the provision of a more stable and secure energy supply (energy autonomy)** that is expressed by reducing the risk of power supply interruptions and can improve the energy security of the campus.

Stimulating innovation is one of the most important benefits, decisive for university institutions and can be exploited in three major directions:

- **development of innovative energy solutions** by facilitating testing and implementation of innovative energy solutions on campus [4] - The Faculty of Power Engineering within UPB collaborated with a photovoltaic energy company to develop an intelligent solar energy management system;
- **creating research opportunities:** data collected by IEMS can be used for research in the field of energy efficiency and development of renewable energy sources - Transilvania University of Brasov, within the Institute for Research and Development (ICDT) has created a research center [5] dedicated to the development of smart energy solutions, with the support of data collected by IEMS;

- **preparing students for an alternative career in energy:** implementing an IEMS can facilitate students access to new development opportunities.

1.2. Examples of IEMS functionalities:

By analyzing the capabilities and benefits of IEMS, a series of functionalities can be extracted and exploited that can be scaled at the level of the entire university campus.

Collecting, monitoring and analyzing real-time data from various sources (buildings, installations, equipment) to identify areas with high consumption and develop optimization strategies. With access to data and their interpretation, **automatic control and prioritization of consumers** can be achieved to adjust energy consumption according to needs, using sensors, actuators and intelligent algorithms. Also, having information on network behaviors and habits, **demand forecasting** can be achieved by using predictive models to predict energy demand and optimize resource production and distribution.

The integration of renewable sources allows facilitating the integration of renewable energy sources (solar, wind) into the campus energy system, with substantial benefits (energy autonomy and bill reduction) for the campus. **Storing surplus energy** by deploying energy storage solutions (in batteries or as heat) to manage surplus energy produced from renewable sources and use it during peak consumption periods, or when solar source, for example, is no longer available.

1.3. Challenges in implementing a IEMS

Debates on switching to renewable energy systems bring to the table actors for and against alike. Thus, for the successful implementation of an IEMS, it is extremely important to understand, assume and meet the characteristic challenges. We have identified and highlighted four essential elements necessary for the implementation and development of IEMS. **Strategic planning** that includes defining specific objectives, identifying the necessary resources and establishing a detailed implementation plan, customized to the campus layout area, with the particular orientations and inclinations of the roofs of the buildings. Also, close **collaboration** with the active involvement of all stakeholders (university administration, students, staff, energy experts) is essential for the success of the project.

An essential component is **initial investments** that can involve significant costs for the purchase and installation of equipment, as well as for software development and staff training. For this aspect, it is essential to identify non-reimbursable or low-co-financing financing, such as those provided by the Ministry of Energy [6]. **Continuous monitoring** of system performance and regular **evaluation** of the results achieved are essential to optimise the functioning of IEMS and demonstrate benefits.

3. ENERGY EFFICIENCY EDUCATION PROGRAMMES (EEEP or 3EP)

These programs can be the key to a **sustainable future** on university campuses and beyond, as this is where future trainers develop, those who once in society, besides being specialists, develop leadership. **Energy Efficiency Education Programs (3EP)** are not just a necessity [7], but a crucial investment in the future of our planet. Implemented on university campuses, they become catalysts for change, cultivating an energy-conscious and responsible generation.

1.4. Types of 3EP

Following our research, we identified several types of 3EP, each characterized by specific elements and ways of addressing the target audience. We have made a selection of them addressed to the 18-25 age segment, characteristic of the period of attending university courses. In order to achieve the 3EP goals, we present the selection made with specific promotion modalities and characteristic examples:

Awareness campaigns can be achieved by informing students and staff about energy issues and the importance of energy efficiency [8]. Also, the use of various communication channels (leaflets, social media posts, seminars) to disseminate information and promote a culture of energy efficiency.

A characteristic example can be represented by organizing an awareness campaign with the 3R slogan "Reduce, Reuse, Recycle" which would lead to a significant increase in awareness of energy issues among students [9].

Courses and training programs can be achieved by developing specialized educational programs to provide knowledge and practical skills in the field of energy efficiency. Also adapting programs to different needs and levels of knowledge (students, administrative staff, technical staff). We have identified one of the important players on the sustainable energy market that offers information and specialized courses [10]. Moreover, the company developed a partnership with the **Faculty of Power Engineering** in which they launched a program of specialization courses in the field of energy efficiency for engineering students, which contributed to the training of qualified specialists in this field [4].

The organization of **interactive workshops** and practical demonstrations facilitates learning and active involvement of participants. Thus, by addressing specific topics (such as saving energy in dormitories, choosing efficient equipment) through interactive and attractive methods, a significant change in student behavior is achieved. On November 10, 2023, the Press Office of **Ovidius University of Constanta** announced through a press release that the university organized an interactive workshop for students on renewable energy and energy efficiency within the university. The workshop on ways to reduce energy consumption in dormitories led to a significant change in student behavior [11].

The development of attractive and user-friendly educational materials (brochures, guides, online platforms) aims to facilitate the dissemination of information and promote responsible behaviour. It is very important to adapt the materials to different categories of audience (students, staff, teachers). We have identified a dedicated online platform with information on energy efficiency, educational resources and practical advice for energy saving [12]. Obviously, a very involved actor in promoting educational materials on climate change is the European Commission. It offers on the online website "Practical advice - Ideas for saving energy and protecting the environment, at home and at work" [13].

1.5. Benefits of 3EP

Once the types of 3EP are identified, their benefits become apparent. We mention the 4 most important benefits identified. **Raising awareness** achieved by educating students and staff about energy issues and the importance of energy efficiency. Awareness also leads to the development of a culture of individual and collective responsibility. **Behaviour change** achieved by promoting responsible behaviours in energy consumption, resulting in significant reductions in energy consumption and costs.

The development of practical competences and skills in energy efficiency helps prepare students for a career in energy. **Stimulating innovation** is identified as a major benefit of these 3EPs that aim to encourage the development and implementation of innovative solutions to optimize resource consumption. Supporting research and development in the field of renewable energy and energy efficiency is also a defining objective.

1.6. Recommendations for 3EP Implementation

In order to obtain the expected benefits, we have made a short list with some key milestones. The 5 recommendations, once achieved, increase the probability of obtaining the expected results. A first recommendation is the **needs assessment** carried out by carrying out an energy audit to identify areas with high energy consumption and establish priorities for the 3EP. It is also necessary to consult students, staff and other stakeholders to identify specific needs and interests.

Once the needs are identified, it is necessary **to develop a comprehensive 3EP program** with the inclusion of a variety of educational methods (awareness campaigns, training courses, interactive workshops, educational materials) to reach a wide audience and adapt the program to different categories of audience (students, administrative staff, technical staff).

Following the simulations of the theoretical model**, the implementation and monitoring of the program will be carried out,** ensuring the minimum requirements of the necessary resources (human, financial) for the efficient implementation of the program. Regular monitoring and evaluation of programme results is executed to identify strengths and weaknesses and make necessary adjustments (reactive feedback loop). In order to ensure the success **of the program, the assumed and active involvement of all stakeholders** is required, ensuring the active participation of students, staff, university management and other stakeholders in the implementation of the 3EP. At the same time, the creation of a dedicated 3EP working group to meet regularly to assess progress and take decisions ensures the coherence of the programme and the achievement of the expected objectives.

Full involvement and **use of available resources** to support the implementation of 3EPs, including educational materials, practical guides and funding programmes, ensures a climate conducive to achieving the objectives. Universities are recommended to collaborate and partner with non-profit organizations, government agencies and private companies to obtain support for 3EPs.

4. EXAMPLES OF GOOD PRACTICES AND SUCCESSFUL IMPLEMENTATIONS OF IEMS AND 3PE ON UNIVERSITY CAMPUSES

There are several approaches that can be implemented to increase the energetic efficiency of a building. For example, presence sensors (i.e. Passive Infrared (PIR) sensors) can be mounted in each room (laboratory, class room, other rooms with different functions). If presence is not detected inside a room, both electrical and thermal energy is saved:

- there can be mounted electrically actuated valves at most of the heaters in the rooms. If the presence is not detected for a while, these heaters are bypassed until somebody enters the room (i.e. two of three heaters can be bypassed when nobody is in the room). The central heating equipment will be always running, but the heating agent (i.e. water) will pass only through open heaters, and in this way, its temperature will decrease slower. Therefore the thermal efficiency of the rooms will increase with a minimum cost of electrical efficiency needed to read presence sensors and to actuate the valves.

- similar with the approach above, there can be mounted switches to automatically turn off most of the lights in the rooms where human presence is not detected. Therefore, until the people are educated to be careful with saving the energy (various means of such methods of education are presented in the next chapter), this electronic system will help in electrical energy efficiency.

The presence sensors are only one option to monitor the activity in the rooms, and to increase the energetic efficiency. Hall sensors [14] can be also mounted at the windows (and possibly at doors). If the windows are opened for a longer period, some of the heaters can by bypassed, since the produced heat will be lost. When the windows are closed, the heaters can operate again at their maximum capacity.

Moreover, the rooms in the Universities can be equipped with temperature sensors. If the room is, in some point in time, into the direct sunlight, its temperature can highly increase, and it will be necessary to stop the heaters in that room.

In the same time, other rooms in the same building must be heated, since these are not heated by the sun. Therefore, the central heating system will operate permanently during the working time, but it will heat only the rooms that need it. Therefore, fewer resources to heat the water (or another heating agent) will be necessary.

There are examples around the world where Universities, by adopting different strategies succeeded to achieve important energy savings. For example, at Aarhus University in Denmark, it was decided to switch off all unnecessary indoor and outdoor lighting, considering the importance of energy saving against some visual effects which could exist. However the managers there considered to continue lighting areas in order to maintain safety and security of the building and of the personnel [15]. Also, at this University, they are running ventilation systems in a controlled way, for shorter times, according also with the indoor temperature and with the quality of the air. Other aspects were taken into account, like the closure of some rooms at night or in the weekends, in order to save the energy for heating and ventilation. By implementing different measures to increase the energetic efficiency, **Aarhus University succeeded to save 17% energy for heating and 16% electrical energy** in the winter 2022-2023 compared with the same period from 2019-2002. This University also has a performance in reducing its emissions, as a group of experts have shown in their studies [16].

Besides creating electronic control systems to avoid unnecessary loses of energy, the Universities must keep into account the thermal rehabilitation of their buildings. For example, University of Padua has adopted a plan to reduce the energy consumption, considering also “upgrading heating and cooling plants, replacing windows and doors, thermal insulation of roofs, replacing lighting fixtures and uninterruptible power supplies (UPS)” [17]. This University also has a consistent activity in increasing awareness for possibilities of energy conservation and sustainable clinical laboratories [18].

Obviously, all programmes and systems must be supported financially, and such major projects are often, depending on their scale, dramatically expensive. Therefore, it is recommended to write **projects that can compete for non-reimbursable funds** [19], as proven by the **University of Life Sciences** "Ion Ionescu de la Brad" of Iasi (USV), which will implement its **own photovoltaic plant** [20, 21]. The project amounts to a total value of over 4.8 million lei, funds requested and obtained through the call for proposals "Supporting investments in new capacities to produce electricity from renewable sources for self-consumption", launched by the Ministry of Energy, with financing from the Modernization Fund (FM). The investment plan is the installation of a generous photovoltaic system of approximately 750 KWpeak, made of over 1,700 photovoltaic panels, which will be deployed on 5,000 square meters. All these will be mounted on the structures of the institution's buildings, including the headquarters, canteen, university campus, and within the institution's Teaching Farm. Thus, it is desired not only to reduce the carbon footprint of the university, but also as an example of good practices in promoting renewable energy sources in the academic environment.

CONCLUSIONS

Intelligent Energy Management Systems (IEMS) are an effective solution for optimizing resource consumption on university campuses. The successful implementation of an IEMS can contribute significantly to reducing costs, increasing energy efficiency and combating climate change.

The successful implementation of 3EPs on university campuses requires careful planning, active involvement of all stakeholders and efficient use of available resources.

The benefits of 3EP are significant and can contribute to creating a more sustainable, efficient and energy-responsible university campus.

3EPs are an essential component of an effective energy management strategy on college campuses. Well-designed 3EP implementation adapted to the specific needs of each university can significantly contribute to reducing energy consumption, reducing costs and combating climate change.

The successful implementation of these solutions will help to significantly reduce energy consumption, CO_2 emissions and operational costs, while increasing energy awareness and student and staff responsibility. Smart energy management systems and energy efficiency education programs are essential tools for reducing energy consumption and CO_2 emissions on college campuses. The successful implementation of these solutions requires an integrated approach, with the active involvement of all actors in the academic environment

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A CRITICAL ANALYSIS AND REVIEW OF THE CONTROLLER PLACEMENT PROBLEM IN 5G SDN SECURED NETWORKS. OPEN ISSUES AND POSSIBLE SOLUTIONS

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Abstract: *This paper attempts a critical analysis of the Controller Placement Problem (CPP) in Software-Defined Networking (SDN) environments, identifies open issues and exploring potential solutions. The strategies to solve the CPP are examined aiming to enhance network performance, scalability, and resilience. SDN is a powerful technology used more and more in different networks. In particular the SDN control is a strong candidate proposed in 5G architectures. This study considers various aspects of CPP, including latency, reliability, and effective load distribution, which are also important in the context of 5G networks. The analysis reviews existing literature, revealing gaps in current strategies, particularly in addressing the dynamic nature of 5G architectures. Special attention is given to the multi-Controller contexts encountered in large networks, where Multi-controller Placement Problem (MCPP) emerges. This overview not only underscores the criticality of CPP in 5G SDN but also outlines some future research directions by our original proposal for a generic architecture for dynamic optimization in CPP.*

Keywords*: 5G networks, Software-defined networking (SDN), Controller placement problem (CPP), Multi-Controller Placement Problem (MCPP), network performance, latency in SDN, 5G SDN scalability*

1. INTRODUCTION

The complex 5G networks, currently developed in the real world, need powerful management and control systems. The integration of Software-Defined Networking (SDN) and Network Function Virtualization (NFV) technologies offer a flexible solution, already adopted in 5G architectures and standards. Usage of intensive virtualization techniques in both SDN and NFV offer the possibility of integration with cloud computing. However, the challenge of effectively integrating SDN and NFV within 5G framework remains a vital topic. This evolution is not limited to just improving the existing infrastructure but marks a strategic transition to more flexible and adaptable network systems, enhanced with cloud computing capabilities.

In SDN based networks a major problem is where to place the SDN controller. This is called controller placement problem (CPP). In large networks where multiple controllers are used, the problem is still more important. Multi-controller implementation of the SDN control plane for large networks can solve the scalability and reliability issues introduced by the SDN centralized logical control principle.

Note that multiple criteria may exist in selection of a particular solution for a Multi-Controller Placement Problem (MCPP). Therefore, a critical analysis of challenges and potential solutions is necessary, to offer the basis for an appropriate design, aiming to meet the requirements and assure the scalability and flexibility. This includes investigating optimal strategies for placing the SDN controller. Such optimizations have as objectives a well-balanced load among the controllers in set, a good real-time response to network events and adaptation to the dynamic requirements of data traffic and services in 5G networks.

This article explores and addresses several challenges in the deployment and optimization of 5G networks using SDN technology. It aims to provide insights into optimizing controller deployment for efficient network management and performance in the rapidly evolving 5G landscape.

Section 2 presents a short overview of related literature. Section 3 outlines the SDN–NFV cooperation within 5G Architectures, to illustrate the role of the SDN control. In Section 4 a few network security and performance issues are summarized. Section 5 defines the CPP topic while Section 6 identifies and analyses the applicable strategies. Section 7 summarizes the conclusions.

2. LITERATURE REVIEW

The study by Kumari and Sairam [1] was one of the first to approach CPP from an optimization perspective, identifying four main areas of criteria considered in the literature: reliability, latency, cost, and multiple objectives. They analyzed specific algorithms for various application scenarios, highlighting the complexity and diversity of this issue [2].

The research conducted by Fancy and Pushpalatha [3] examined different CPP resolution techniques, focusing on various metrics and the characteristics of the proposed solutions. The study also emphasized the importance of optimizing the relationship between controllers and switches, considering this an essential aspect for the efficiency of SDN networks.

The work [4] by Ayo et al. explored CPP in two distinct scenarios: minimizing the number of controllers and optimizing their locations. Their approach highlighted the complexity and tradeoff in choosing between a low number of controllers with extended capabilities versus a broader distribution with reduced individual capacity. This indicates that solutions for CPP must consider a wide range of factors, including the communication latency between switches and controllers, as well as among the controllers themselves.

Another essential aspect in CPP is the dependence of the optimal solution, on topology and the controller load factor. This is an example of the multi-criterial characteristics of the CP problem. The study by Rahman et al. [5] demonstrated the usefulness of a heuristic algorithm to dynamically manage the controller load, taking into account the average flow requests between switches and controllers. This highlights that the proposed solutions for CPP must be flexible and adaptable to different network configurations and traffic variations.

Richard Wang et al. [6] proposed using wildcard rules in the matching tuple to reduce the load on the controller. Wildcard rules in OpenFlow switches are used to handle large volumes of client traffic without involving a central SDN controller for each connection. These rules are generated by algorithms such as "partitioning algorithms" to efficiently distribute traffic across server replicas.

During conversion, microflow rules are temporarily installed by the controller to ensure that ongoing connections on the original replica are intact, thereby reducing interruptions and controller involvement in routine traffic processing. This approach minimizes the load on the SDN controller and enables scalable and adaptive server load balancing

A persistent challenge in the field of CPP is determining the optimal number of controllers and also their strategic placement in the network. Studies [7] and [8] have addressed these aspects, emphasizing that the placement and number of controllers are essential for balancing the load in the network and ensuring efficient traffic distribution. This is crucial to ensure optimal performance and enhanced resilience in 5G networks.

The study [9] revealed that HTTP applications constitute a significant proportion of internet traffic, necessitating a strategic approach in managing this traffic through OpenFlow switches. This underscores the importance of considering the predominant types of traffic in the design and implementation of CPP solutions.

The proposed approaches the CPP from heuristic solutions to optimized algorithms for controller load management, demonstrating the complexity and multidimensional nature of CPP. It is evident that any viable solution for CPP must be robust, flexible, and consider a multitude of factors, including network topology, data traffic, and controller capacity. Last but not least the scalability of solution should be considered.

3. SDN – NFV COOPERATION WITHIN 5G ARCHITECTURES

The SDN and NFV - based management and control entities are proposed as main cooperating functional components in 5G architectures [10], [11], [12]. This approach is also used in 5G network slicing. Two types of SDN of controllers are embedded in the general NFV reference architecture. Each controller centralizes the control plane functionalities and provides an abstract view of all the connectivity-related components it manages (Fig. 1).

- *Infrastructure SDN controller (IC)- sets up and manages the underlying networking resources* to provide the required connectivity for communicating the virtualised network functions VNFs (and their components); The Virtual Infrastructure Manager (VIM) manages the ICs; the IC may change on-demand the infrastructure behaviour, according to VIM specifications, adapted from tenant requests. IC provides an underlay to support the deployment and connectivity of VNFs.
- *Tenant SDN controller (TC)-* (Note that the tenant is defined as a generic user of a slice) is instantiated in the tenant domain - as one of the VNFs, or as part of the Network Management System (NMS); *TC dynamically manages the pertinent VNFs* used to realize the tenant's network service(s). These VNFs play the role of an underlying forwarding plane resources of the TC. The applications running on top of TC (e.g., the Operation System Support - OSS) triggers the operation and management tasks that the TC carries out. Each tenant can independently manage on its slice(s). TC provides an overlay comprising tenant VNFs that, properly composed, define the network service(s).

The controllers' southbound interfaces can use programmable protocols (e.g., OpenFlow, NETCONF or I2RS).

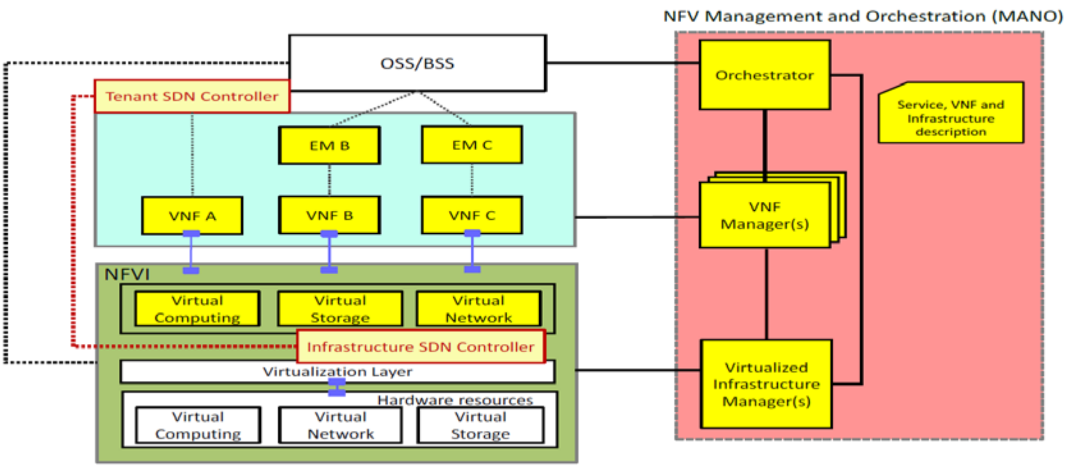

FIG. 1. Two levels of SDN controllers in 5G NFV-SDN based architecture (to achieve slicing) [source: ONF-2016-TR256]

The SDN have controller's different views on resources. The IC is not aware of the number of slices that utilize the VNFs it connects, nor the tenant(s) which operates such slices. For the TC the network is abstracted in terms of VNFs. The TC does not know how those VNFs are physically deployed. However, the IC and TC have to coordinate and synchronize their actions. The service and tenant concept mentioned here can be extended to higher abstraction layers by applying the recursion principle.

The problem placement of SDN controllers (CPP) is particularly of interest for Infrastructure Controllers (IC) in large 5G networks, given the geographical distribution of the network regions.

4. NETWORK SECURITY AND PERFORMANCE

Enhanced network security directly influences performance, ensuring reliability. It involves protective measures, like firewalls and intrusion detection systems, guarding data integrity and confidentiality. Encryption, e.g., SSL/TLS, secures data in transit. High-performance networks feature swift data transfer, low latency, and minimal errors. Software-Defined Networking (SDN) and Network Function Virtualization (NFV) enhance performance. Balancing security with performance is essential. Latency, crucial in SDN, varies based on factors like controller placement. Researchers propose solutions, such as considering propagation latency, integrating metrics like throughput, and reducing controller-switch latency.

As for 5G, the 5th generation of mobile communications brings numerous improvements compared to the previous generation such as:

• Use of AES-256 versus AES-128 used for data encryption and privacy within 4G;
• Network segmentation to isolate different parts of the network;
• Optimized support for IoT communication;
• Mutual authentication between device and network;
• "Lightweight" encryption to facilitate secure communication between IoT devices with low power consumption. Among the standardized algorithms, we mention SIMON and SPECK (NSA, 2014).

In CPP placement context, securing the control architectural plane involves protecting and securing the communication channels for messages exchanged between network devices and the controller, implementing strong authentication mechanisms within the control plane to prevent unauthorized access and implement security measures to protect the controller as it manipulates the entire network.

5. CONTROLLER PLACEMENT PROBLEM IN SDN

SDN Controller Placement Problem (CPP) has as main target to find an appropriate distribution of controllers, while meeting different criteria of optimization. A single controller is insufficient to manage large-scale networks, necessitating the use of multiple controllers to ensure proper network control and scalability. The CPP result is to determine the optimal number of controllers [13] and their strategic locations within the SDN network, while meeting the requirements and, in particular, specific scalability and Quality of Service (QoS) needs.

Fig.2 illustrates the architecture of a multi-controller SDN network still able to construct a logically centralized vision on the network. In this configuration, the data path is marked with a red line, while the control path is represented with dashed lines, demonstrating a clear and efficient separation between the two essential functions in the SDN network architecture [14]. Therefore, addressing CPP in SDN requires careful analysis of the network topology and specific requirements to ensure efficient and scalable network management.

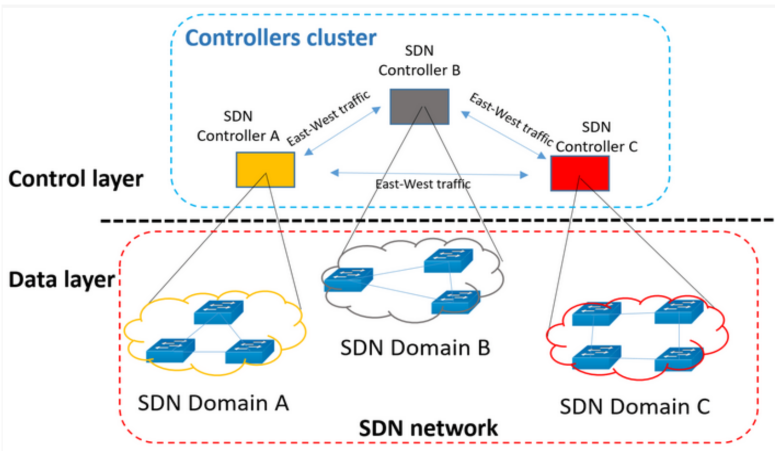

FIG. 2. Multi-controller SDN architecture

In an SDN controller's distributed architecture, network performance fundamentally depends on controller placement. This problem is still valid in a single physical controller case, though the problem is less impactful. Heller, Sherwood, and McKeown formulated the CPP in [15] as a facility location issue. They use metrics such as average latency and worst-case latency to optimize controller layout. Through a comprehensive topology analysis, they show that in many cases a single controller is sufficient to achieve response time targets. The study highlights the trade-offs between optimizing for average and worst-case latency and provides practical guidance for SDN deployments. According to [16], a single controller is deemed sufficient for managing networks in most SDN-based networks. A significant issue in the single controller system is a single point of failure. Conversely, in large-scale networks, a single controller can act as a network bottleneck and create performance issues.

Hence, in larger networks, multiple controllers are necessary. This point is vital for enhancing network performance, latency between forwarding elements and controllers, network reliability and robustness, and scalability.

The core of CPP lies in determining the optimal number and locations of controllers within an SDN network, a challenge that significantly impacts performance, reliability, and efficiency. The infrastructure is commonly modeled as a graph, G = (V, E, U), where V represents the set of switches, E the set of physical links, and U the set of controllers [17]. The goal is to optimize the value of k (number of controllers) and the U → V mapping, aiming to minimize, e.g., switches-controllers communication latency as the primary objective.

CPP studies often consider the shortest path lengths between each pair of nodes, with the minimization of delay as a key goal in the optimization function [18]. The CPP is an optimization challenge that can be based on data or various metrics to find the minimum or maximum cost like the optimal number of controllers, SC delay, or controller synchronization time [19][20]. This approach aids in determining the number, types, and placement locations of controllers, crucial for network performance and service quality.

CPP is recognized as a non-deterministic NP-hard problem, similar to the facility location problem, necessitating intelligent planning and decision-making to achieve optimal placement and satisfactory results [21][22].

In the placement of multiple controllers, several factors impact SDN performance, including reliability, controller load balancing, latency, operational costs, and event response time. These factors can be explored in more detail as follows:

→ Latency in the control plane is a crucial factor in CPP, heavily influenced by the distance between network nodes. Propagation and processing times are significant for packet transmission. Propagation latency is the response time between controllers or switches, affected by their distance. Additionally, processing latency is strongly affected by controller load. Optimizing latencies affects both controller-to-controller (CC) and switch-controller (SC) delays. SC latency exceeding a threshold leads to increased network latency, affecting network responsiveness.

→ Controller load balancing is essential as an increasing number of switches controlled by a single controller can overload it, resulting in queuing delays and unprocessed requests. Achieving balanced load distribution among SCs is challenging when minimizing controllers and switch allocations.

→ Fault tolerance is vital, as the loss of a controller directly impacts the switches it controls, hindering network functions. Reducing the number of controllers while ensuring reliability is critical in order to maintain continuous network functionality and minimizing **downtime.**

→ Determining the optimal number of controllers becomes complex with unplanned switches linked to a controller, impacting network performance. Various approaches, such as traversal searching, are time-consuming when seeking optimal performance.

→ Cost considerations play a significant role in deploying controllers efficiently, affecting overall expenditure. Balancing CAPEX and OPEX is essential in minimizing costs.

→ Inter-controller communication is essential for maintaining global consistency in SDN. Communication between controllers influences the end-to-end communication performance among switches under different controllers. Optimizing the controllers' placements in such a context is necessary, in order to achieve a high efficiency of the control plane, seen as a whole.

Several specific algorithms have been developed to find an optimum solution for a single given criterion; however, the optimization for MCPP problem is natively a multi-criteria one, (as it was shown above). The objective is to achieve an overall optimization on controller placement, by applying multi-criteria decision algorithms (MCDA) [23][24]. The input of MCDA is a set of candidates (here an instance of controller placement is called a candidate solution). In the optimization process different criteria can be assigned different weights, depending on particular objectives of the network owner.

6. STRATEGIES

Software-Defined Networking (SDN) faces complex challenges, including controller scalability, network latency, load balancing, and cost-efficiency.

Addressing the challenges in SDN networks involves complex issues such as scalability, reliability, and delay optimization.

For these types of problems, there are some possible solutions as shown in the following table:

Table 1. Overview of some problems

Problem	Possible solution
Scalability	Distributed controller deployment
Reliability	Redundant controller configurations
Delay optimization	Strategic controller placement

One of the primary challenges in SDN networks is ensuring that the architecture can scale effectively to accommodate growing network demands. As networks expand, the centralized control plane may become overwhelmed, leading to performance bottlenecks and decreased network efficiency.

One solution to address scalability challenges is the deployment of multiple distributed controllers. Each controller is responsible for a specific segment or domain of the network; thus, the load on any individual controller is lower. The controllers can handle a portion of the network's traffic independently.

A unique controller in an SDN network is a single point of failure). To enhance reliability, redundant controller configurations can be implemented. This involves setting up backup controllers that are ready to take over in the event of a primary controller failure. These backup controllers are kept synchronized with the primary controller's state so that they can seamlessly assume control of the network if needed. This approach minimizes downtime and ensures continuous network operation, even when the primary controller encounters issues.

Minimizing delay or latency in SDN networks is crucial for delivering real-time services and improving the overall user experience. High latency can lead to delays in data transmission and processing, negatively impacting applications like video conferencing and online gaming these latencies are related to data plane operations, distinct from the communication processes done in the control plane.

Strategic controller placement is essential for optimizing delay in SDN networks. This approach involves carefully selecting the locations where controllers are deployed within the network. To achieve this, network traffic patterns must be thoroughly analyzed to identify hotspots or areas with high traffic. Controllers should be strategically placed closer to these hotspots to reduce the distance that control messages need to travel, thus minimizing latency.

By analyzing network data and understanding the flow of traffic, network operators can determine the optimal placement of controllers to ensure minimal delay. This approach can significantly enhance the performance of latency-sensitive applications and services.

Addressing the challenges in SDN networks requires a multi-faceted approach. Scalability can be improved through the deployment of distributed controllers, while reliability is enhanced by implementing redundant controller configurations. Delay optimization relies on strategic controller placement to minimize latency. By adopting these solutions, SDN networks can overcome these challenges and provide efficient and reliable communication services to users. The continued development of SDN technologies and innovative solutions will play a pivotal role in shaping the future of networking and addressing the evolving needs of modern communication systems.

7. CONTRIBUTION –AN ARHITECTURE FOR DYNAMIC OPTIMIZATION IN CPP

In this chapter we propose a generic SDN management and control architecture aiming to optimize the controller's placement through a SDN network, in a dynamic way, based on integrating advanced traffic analysis capabilities. The architecture is shown in the Fig. 3.

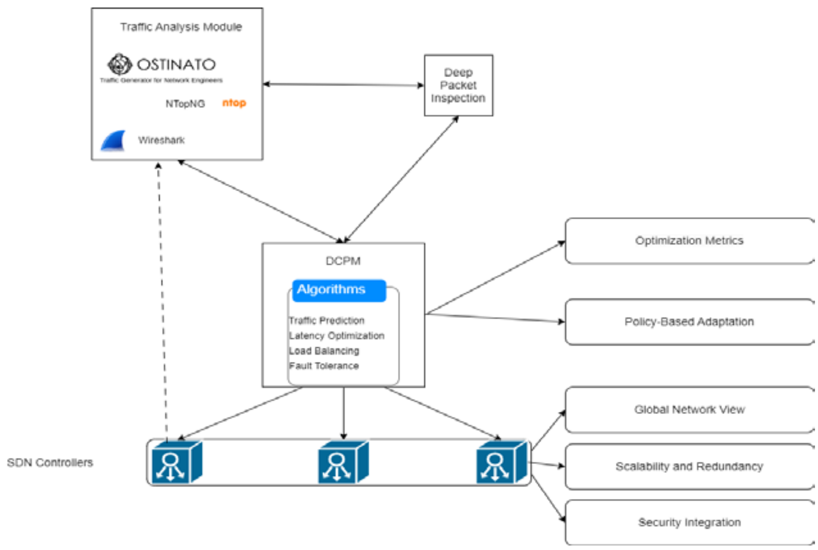

Fig. 3. System architecture proposal for dynamic optimization in CPP

Our proposal integrates a TAM (Traffic Analysis Module) working together with a DPI (Deep Packet Inspection) in order to analyze network traffic. TAM has the role of providing flow-level visibility and DPI conducts in-depth analysis of packet content. The connection between them is bidirectional suggesting the traffic analysis capability by interacting between flow-level and packet-level.

The DCPM (Dynamic Controller Placement Manager) will use the information provided by DPI and TAM to place the SDN controller dynamically, by using algorithms such as Round Robin (for uniform traffic distribution between the controllers), network latency-based algorithms, genetic algorithms and so on.

The Optimization Metrics could be QoS based, but as well other criteria could be considered, having different priorities They are connected to the DCPM and influence the optimization of network performance.

Connected to the DCPM and the Optimization Metrics block, the Policy-Based Adaptation provides policy definition using the YANG modeling language.

SDN controllers (e.g., ONOS, ODL, RYU, etc.) enable communication between various network devices and applications, incorporating dynamic adjustments to the flow tables to accommodate real-time traffic requirements. Even more, in order to obtain a much scalable architecture, the controller can provide traffic information to the TAM, avoiding the overloading of the DCPM by letting it to collect information about all traffic in the network.

The Global Network View represents a centralized database connected to the SDN controllers that has the purpose of maintaining a real-time global view of the network. This offers the controller a perspective that helps it in the decision-making process.

The component of Scalability and Redundancy employs a microservices approach and active-standby configurations for redundant controllers by using Kubernetes orchestration, which plays a pivotal role by automating the deployment, scaling, and management of these microservices. This integration ensures that the SDN controller operates within a scalable and resource-efficient network environment.

The Security Integration block (SI) provides secure communication using OVS (Open vSwitch) security features, through using TLS (Transport Layer Security) protocol.

Our study addressed the CPP problem in SDN context, proposing an architecture which can provide an adaptive optimization for CPP. Featuring key modules as DPI, Traffic Analysis and Dynamic Controller Placement, resulted a holistic and dynamic optimization strategy for the controller placement. To emphasize the importance of security integrations, QoS and policy-based adaption the architecture encapsulates a comprehensive solution. The microservices-oriented design assures scalability while the efficiency over the resource’s usage is handled by Kubernetes. Our SDN architecture provides an efficient and solid resolution to the CPP, promoting a robust and high-performing network infrastructure.

8. CONCLUSIONS

Placing the controller efficiently can significantly improve performance metrics such as propagation latency, reliability, load distribution, and failure resilience. This study provides a brief introduction to Software-Defined Networking (SDN), examines its architecture, reviews related work, and identifies weaknesses in both single-controller SDN and multi-controller (distributed) SDN evolution. As a result, it becomes evident that, in order to ensure scalability and reliability, large-scale SDN networks necessitate multiple controllers. Such comparisons can aid in progressing towards a dependable solution for CPP in SDN.

Future research must pivot towards developing dynamic load balancing strategies, integrating Machine Learning for load prediction, and enhancing security in 5G-integrated SDN environments. Key areas like IoT, satellite networks, and IoV also require novel controller placement techniques. The ultimate goal is to optimize controller distribution for improved network performance, scalability, and reliability.

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WIRELESS TRANSMITTER FOR OPTICAL COMMUNICATION WITH FREQUENCY-MODULATED LASER CARRIER

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Abstract: *Interest in the use of unguided optical systems is growing, due to the development of wireless mobile and indoor communication systems as well as the applications of lasers in space technology. The proposed laser transmitter, with frequency-modulated carrier, represents the optical transmitter of a wireless optical communication system, for transmitting audio signals on laser carriers, which can be used both inside buildings and outside, for distances estimated according to system parameters. In the paper are presented elements of design of the electrical diagram of principle, as well as analysis by SPICE simulation of the designed circuit. The results obtained by SPICE simulation synthesize the operation of the laser transmitter, allowing an optimization of the parameters of the component circuits.*

Keywords: *wireless transmitter, laser carrier, MF modulator, optical transmitter*

1. INTRODUCTION

Optical communication systems offer a broad spectrum of possibilities due to the diverse modulation and detection methods [3,6], types of optical channels, and operating conditions. This encompasses interior optical communication systems, primarily utilizing laser diodes and light-emitting diodes as optical sources for transmission [5,8,10]. The modulation process involves the excitation mechanism, wherein the optical signal is modulated with a pulse-modulated subcarrier.

Unguided optical communications find applications both indoors and in external short links [1,2,4]. Designing outdoor optical communication systems requires consideration of the significant atmospheric attenuation variations due to changing weather conditions. The input information undergoes encoding and is applied to a modulator excitation device, steering the electro-optical modulator. This modulator, positioned inside or outside the laser cavity, modulates the laser beam.

The modulated laser beam is collimated by the transmitting optical antenna, traverses the transmission medium (such as vacuum space, atmosphere, controlled atmosphere guide, or optical fiber), and is captured by the receiving optical antenna [1,7,9]. The concentrated laser radiation is then directed to an optical receiver. At the photodetector's output, an electrical signal is obtained through direct detection or heterodyne detection, which undergoes further processing in a radio receiver. The resulting signal is decoded, yielding the output information.

The modulation of the optical carrier distinguishes itself from radio frequency carrier modulation due to different processes, characteristics, and parameters of the optoelectronic devices involved.

Frequency modulation offers a notable advantage as its inherent detection scheme eliminates noise, provided the received signal surpasses noise sources.

Transmitting information through frequency variations, rather than amplitude changes, ensures a noise-resistant signal at the audio receiver, particularly in the presence of electromagnetic interference and scintillations.

2. PRINCIPLE OF OPERATION

The core of the laser transmitter is a voltage-controlled oscillator, comprising an integration circuit and a hysteresis comparator [3]. This element executes frequency modulation of audio signals (20*Hz*-16*kHz*), generating a pulsed signal output with a frequency ranging from 140*kHz* to 260*kHz*, with the carrier signal frequency set at 200*kHz*.

The FM modulator [3,6], a voltage-controlled oscillator, switches the laser diode between two discrete current levels, incorporating encoded information into the laser diode driver's signal. This process generates a frequency-modulated subcarrier wave, essentially a position pulse modulation (PPM) signal operating at around 100*kHz*. The supply current to the laser diode is adjustable within the range of 0-20*mA*.

A voltage regulator provides the supply current to the laser diode via the laser driver, resulting in the emission of coherent, wavelength laser beams with specific characteristics. The laser diode emits optical pulses synchronized with the PPM subcarrier. The audio amplifier circuit amplifies and isolates the input signal, transmitting it to the modulation circuit.

The voltage-controlled oscillator, operating at a frequency of 200*kHz*, comprises an integrator (CI_3) and a hysteresis comparator circuit (CI_4), serving a critical role in the modulation process (Fig. 1).

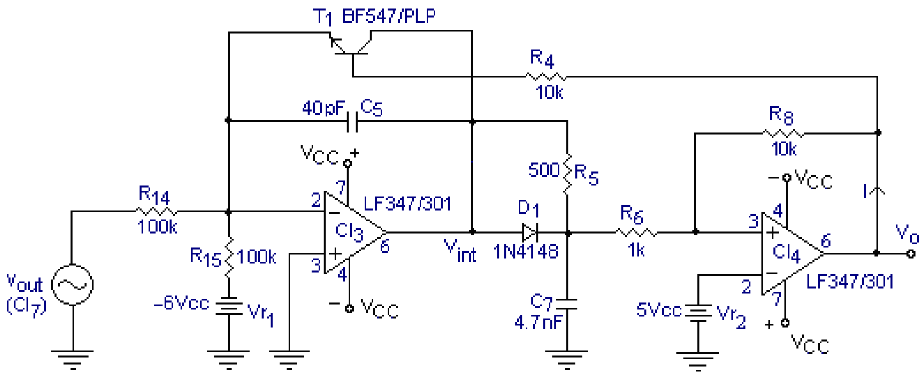

FIG. 1. Wiring diagram of the voltage-controlled oscillator

The reference voltage (V_{r2}) of the hysteresis comparator has been set at 5*Vcc*. The comparator output voltage is, $V_o \in \{V_{oH}; V_{oL}\}$ where, $V_{oH} = 12V$ and $V_{oL} = -12V$. The comparator switches when $V_+ = V_{r2}$. Current *I* (FIG. 1) is determined with the relations:

$$I = \frac{V_{oH} - V_{in}}{R_6 + R_8} = \frac{V_{oH} - V_{r2}}{R_8} \quad \Rightarrow \quad V_{in} = \frac{V_{r2}(R_6 + R_8) - V_{oH} R_6}{R_8} = V_{r2}\left(1 + \frac{R_6}{R_8}\right) - V_{oH}\frac{R_6}{R_8} \qquad (1)$$

For integration levels, the following values are obtained:

$$V_{PL} = V_{r2}\left(1 + \frac{R_6}{R_8}\right) - V_{oH}\frac{R_6}{R_8} \cong 4{,}3V \qquad (2)$$

$$V_{PH} = V_{r2}\left(1+\frac{R_6}{R_8}\right) - V_{oL}\frac{R_6}{R_8} \cong 6{,}7V \tag{3}$$

The upper integration limit is given by the V_{PH} voltage plus the voltage falling on diode D_1, resulting in approximately 6,7*V*, as seen from the waveforms obtained by simulation. The high-frequency transistor T_1, connected in bypass to the integration capacitor C_5, provides the discharge path of the capacitor, which discharges completely in a very short time, fixed to $0{,}5\mu s$.

The voltage at the output of the integrator, for $V_{out} = 0$ (V_{out} is the voltage at the output of the audio amplification circuit), is given by:

$$V_{\text{int}} = -\frac{1}{R_{15}C_5}\int V_{r1}dt = \frac{6}{100\cdot 10^3\cdot C_5}\cdot t = 6{,}7V \tag{4}$$

For a subcarrier frequency of 200*kHz* and taking into account the discharge time of the integration capacitor, the integration time results, $t = 4{,}5\mu s$.

Through the audio signal amplification circuit (achieves frequency-dependent amplification at 20*dB/dec*), the audio signal frequency is practically converted into a voltage level ($V_{out} \neq 0$), which is applied to the integrator input, summing up with the DC voltage $V_{r1} = -6V$. Thus, depending on the V_{out} value, the integration slope changes, resulting in frequency modulation of the 200*kHz* subcarrier.

The voltage at the output of the integrator, for, $V_{out} \neq 0$ is given by:

$$V_{\text{int}} = -\frac{1}{R_{15}C_5}\int V_{r1}dt - \frac{1}{R_{14}C_5}\int V_{out}dt = -\frac{1}{RC_5}\int\left(V_r + V_{out}\right)dt = 6{,}7V \tag{5}$$

The maximum amplitude of the V_{out} signal (obtained at the frequency of 16*kHz)* has been set at 2*V* (above this value the distortion of the signal that controls the power supply of the laser diode is observed). Substituting in relation (5) and taking into account the phase of the audio signal, results in the maximum time, respectively, the minimum integration time: $t_{\min} = 3{,}3\mu s$; $t_{\max} = 6{,}6\mu s$.

The limit frequencies of the FM-modulated subcarrier shall be determined:

$$T_{\min} = t_{\min} + t_{desc} = 3{,}8\mu s \quad \Rightarrow \quad f_{\max} = \frac{1}{T_{\min}} \cong 260kHz \tag{6}$$

$$T_{\max} = t_{\max} + t_{desc} = 7{,}1\mu s \quad \Rightarrow \quad f_{\min} = \frac{1}{T_{\max}} \cong 140kHz \tag{7}$$

The division circuit (bistable type D) (CI_{6A} – FIG. 2) divides the frequency of the V_o signal by 2 and restores symmetry. It follows that the signal frequency at the output of the frequency divider is between 70k*Hz* and 130*kHz.*

3. SPICE ANALYSIS OF DESIGNED SUBSYSTEMS

The SPICE analysis diagram of the laser transmitter for audio signals, with frequency-modulated subcarrier, is shown in Fig. 2.

The frequency simulation was performed taking into account the transfer functions of the analyzed circuits. Time domain analysis was performed over several periods of time, obtaining waveforms for electrical signals in the circuit.

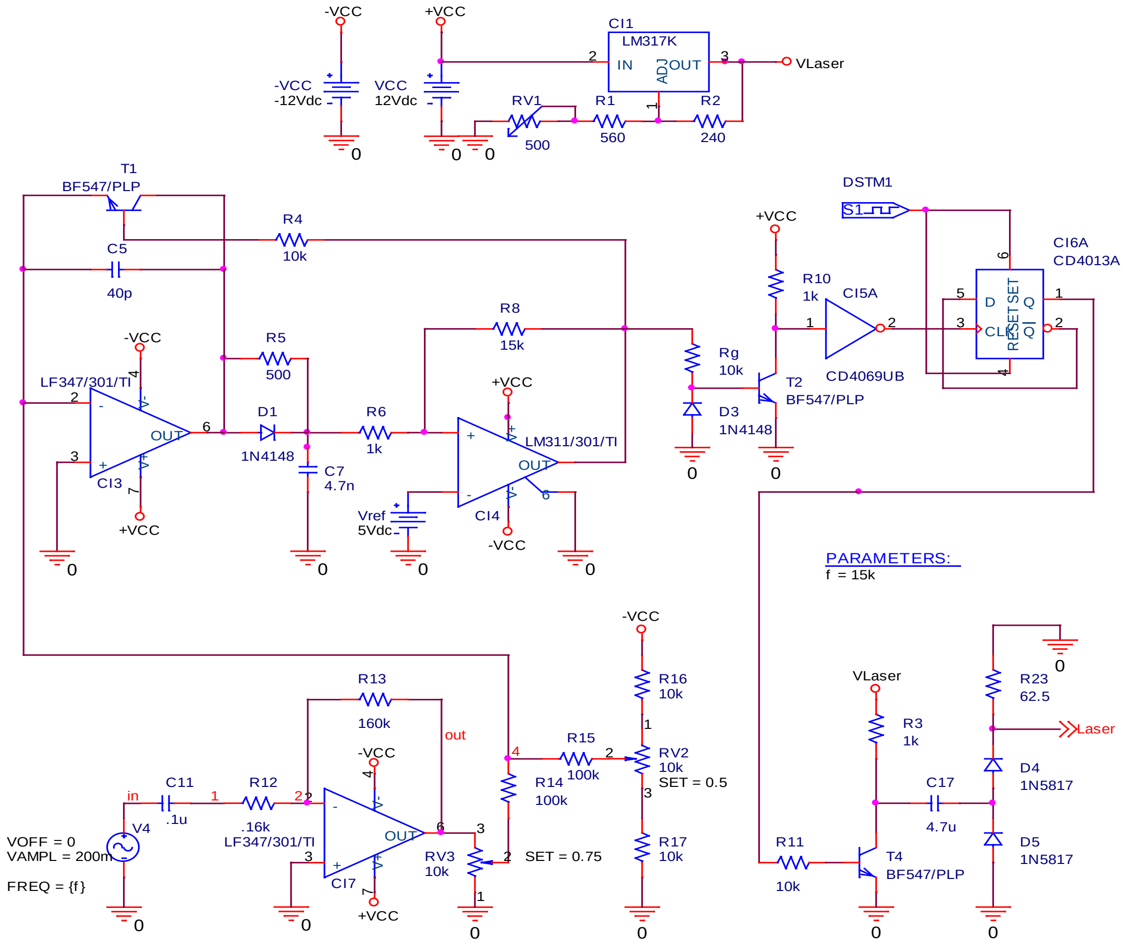

FIG. 2. SPICE Analysis Diagram of the Laser Transmitter

Figure 3 shows the frequency response of the audio signal amplification circuit. It is noticed that the amplification of audio signals is 20*dB/dec*, the maximum amplification of 60*dB*, obtaining at a frequency of about 20*kHz*.

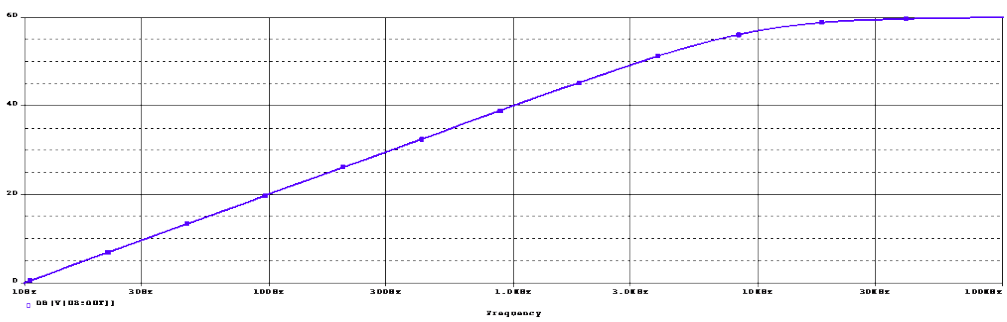

FIG. 3. Frequency analysis of audio signal amplification circuit

Below are presented the waveforms for the analyzed circuit, namely: the signal from the output of the amplifier circuit (V_{out} – violet), the signal from the integrator output (V_{int} – blue), the signal from the comparator output (V_o – red) and the supply voltage of the laser diode (green).

Figure 4 shows the waveforms for $V_{out} = 0$. It is noticed that in this case the oscillation frequency of the oscillator controlled in voltage is 200*kHz*, and the frequency of the laser supply current is 100*kHz*. The maximum voltage at the integrator output is 6,1*V* and the laser supply voltage is 2,5*V*, resulting in a maximum supply current of 40*mA*.

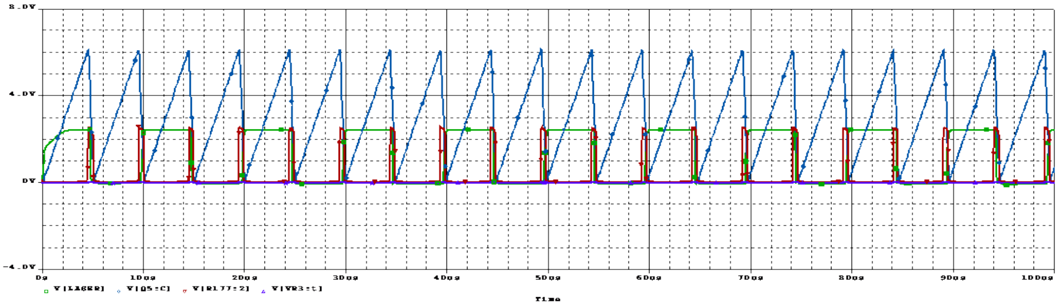

FIG. 4. Waveforms for $V_{out} = 0$

Figures 5 and 6 show waveforms for $V_{out} \neq 0$ $(V_{AMPL} = 200mV)$, at modulating audio signal frequencies of 5*kHz* and 16*kHz*, respectively.

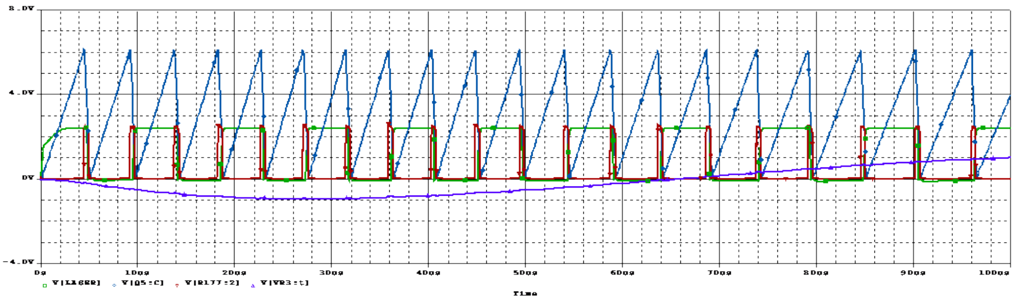

FIG. 5. Waveforms for $V_{out} \neq 0$, f = 5*kHz*

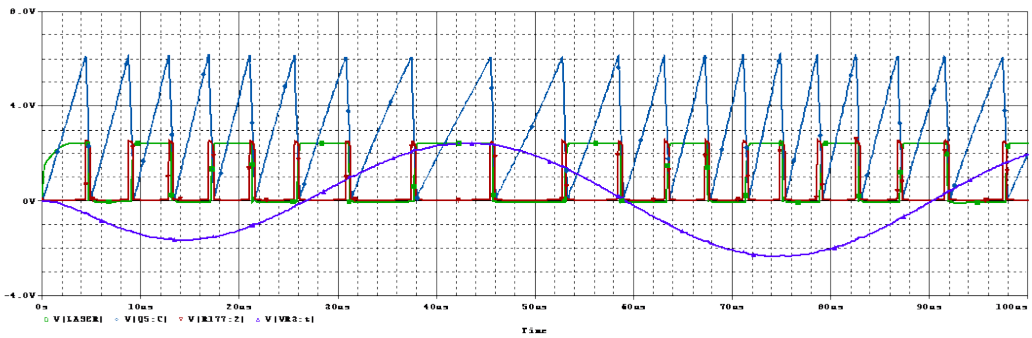

FIG. 6. Waveforms for $V_{out} \neq 0$, f = 16*kHz*

From the analysis of the waveforms presented it can be seen that the frequency of the MF subcarrier depends on the frequency of the audio signal, which varies between 70*kHz* and 130*kHz*.

Figure 7 shows the waveforms for a $V_{AMPL} = 250mV$ (f = 16kHz) input signal applied to the input of the amplifier circuit. The amplitude of the signal applied to the input of the integrator circuit (CI_3), through the resistive divider made with RV_3, represents 1/4 of the signal at the output of the line amplifier (CI_7). It is noticed that the line amplifier saturates, which has the effect of distorting the received signal. The higher the voltage at the output of the line amplifier, the more distorted the received signal will be.

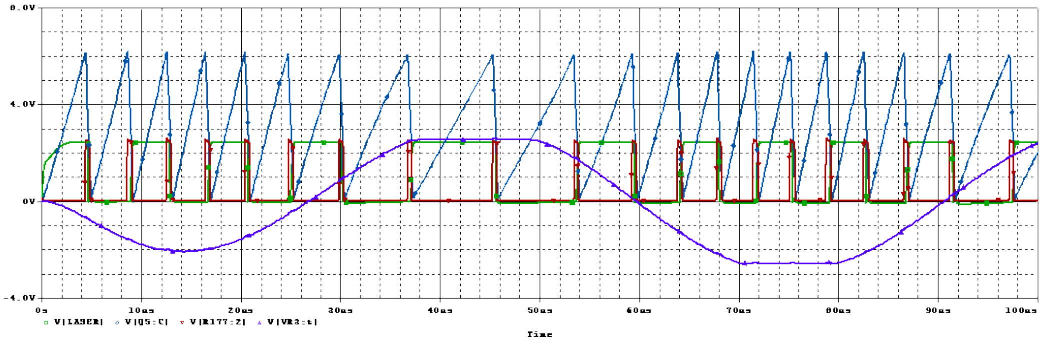

FIG. 7. Waveforms for $V_{AMPL} = 250mV$, f = 16kHz

Figure 8 shows waveforms for a 500mV audio signal with a frequency of 16kHz. Stronger saturation of the line amplifier is observed.

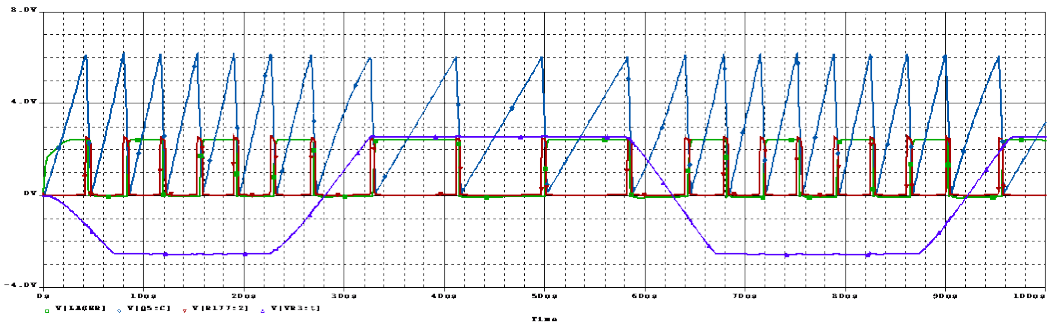

FIG. 8. Waveforms for $V_{AMPL} = 500mV$, f = 16kHz

CONCLUSIONS

The configuration of a laser transmitter is fundamentally dictated by the chosen optical modulation method, the transmission medium, and the targeted range. In this context, frequency modulation has been selected as the modulation method, with the Medium Frequency (MF) frequency-modulated signal adopting Pulse Position Modulation (PPM). The PPM signal is characterized by pulsed signals, where the pulse position is proportionate to the amplitude of the analog modulating signal. Specifically, the MF signal is derived from the Pulse Width Modulation (PWM) signal, generating pulses with a fixed duration corresponding to the rising edge of the PWM signal pulses. This mechanism results in pulses whose positioning is contingent upon the analog input signal.

Following an in-depth SPICE analysis, conducted for a subcarrier frequency of 200kHz and established reference voltage levels V_{r1} (–6Vcc) and V_{ref} at the comparator CI_4 (5Vcc), it was determined that the maximum amplitude of the signal at the output of the audio amplification circuit should be carefully controlled to avoid distortion of the MF signal.

The frequency-modulated carrier operates above the audio frequency band, strategically positioned outside the frequency bands associated with ambient noise perception. This placement minimizes the impact of potential sources of disturbances, as these disturbances exhibit low levels in the pass band of a meticulously designed receiver operating at ultrasonic frequencies. Additionally, the frequency-modulated subcarrier displays robust immunity to detecting nonlinearity in photodetectors.

The waveforms obtained through SPICE simulations, both in the time domain and frequency domain (amplitudes, periods, amplifications, etc.), correspond remarkably well with the theoretical results derived during the design phase. This alignment serves as a robust verification of the functionality and stability of the proposed system. Moreover, the designed system underwent experimental validation, demonstrating a commendable concordance between the experimental and theoretical results obtained during the design phase, as well as alignment between the experimentally acquired waveforms and those obtained through SPICE simulation. This comprehensive validation process underscores the reliability and efficacy of the designed laser transmitter system.

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BLUETOOTH ENVIRONMENTAL MONITORING SYSTEM

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Abstract: *The primary goal of this project is to construct an environmental monitoring system integrating a Bluetooth HC-06 module. Drawing upon acquired expertise, the project resulted in the development of a functional system capable of gathering sensor data, transmitting it wirelessly to a mobile device via the Bluetooth module, and displaying it in real-time. The utilization of the FreeRTOS operating system facilitated synchronous data collection, orchestrated through tasks synchronized by semaphores, thereby guaranteeing the integrity of real- time data acquisition and transmission.*

Keywords: Bluetooth, Arduino, Monitoring System, Display, Breadboard, FreeRTOS, Sensors

1. INTRODUCTION

Environmental quality monitoring is a fundamental service targeted at observing and predicting the dynamics of both qualitative and quantitative aspects of environmental components. It involves a systematic characterization and surveillance of environmental conditions, essential for understanding prevailing states and trends. Environmental monitoring systems play a crucial role in ensuring human health, safety, and well-being by continuously assessing various environmental parameters. In recent years, Bluetooth environmental monitoring systems have emerged as effective tools for real-time monitoring of environmental conditions in various settings. However, existing solutions often face challenges related to sensor integration, task management, and user interaction. In this paper, I present a novel Bluetooth environmental monitoring system that addresses these challenges through the integration of a flame sensor and a DHT11 sensor, the utilization of FreeRTOS for task management, and the development of a custom phone application for user interaction. By leveraging these innovations, this system offers enhanced functionality, reliability, and usability compared to existing solutions.

In this paper, a comprehensive examination of environmental monitoring utilizing Bluetooth technology is presented. The purpose is to provide both a state-of-the-art overview of current methodologies and a user-friendly tutorial suitable for novice readers. Moreover, seasoned researchers seeking to delve deeper into the subject matter will find valuable insights within this discourse. The paper is structured as follows to fulfill these objectives: commencing with a detailed exposition on the system overview (Section 2) and subsequent delineation of system implementation (Section 3), followed by an elucidation of the proposed system design (Section 4) and presentation of experimental findings (Section 5).

While the primary focus remains on environmental monitoring via Bluetooth technology, a brief discussion on the significance of employing FreeRTOS for task prioritization is also included. This aspect is particularly crucial for ensuring safety, as even a slight delay can have significant implications.

The conclusion emphasizes the successful integration of sensors, real-time task management, and user interaction capabilities, resulting in enhanced functionality, reliability, and usability of the system. Additionally, a roadmap for potential future endeavors in environmental monitoring utilizing Bluetooth technology is outlined, offering avenues for further exploration and advancement in the field.

2. SYSTEM OVERVIEW

Hardware components

A. Bluetooth module HC-06

The Bluetooth module employed in this system adheres to the Bluetooth 2.0 protocol and operates solely as a slave device. Utilizing the frequency hopping spread spectrum technique, denoted FHSS, the HC-06 module mitigates interference from other devices and facilitates full-duplex transmission.

Key advantages associated with the HC-06 module include its ability to facilitate wireless communication over short distances (typically less than 100 meters), as well as its affordability and user-friendly nature.

Communication via the HC-06 module is facilitated through the Universal Asynchronous Receiver Transmitter (UART) interface. This interface enables seamless connectivity of the module with any microcontroller or personal computer equipped with a RS232 (Recommended Standard 232) port.

B. DHT11 temperature and humidity sensor

The DHT11 sensor incorporates a negative temperature coefficient (NTC) thermostat for temperature measurement and a capacitive sensor for humidity measurement. Additionally, it integrates an 8-bit microcontroller responsible for transmitting temperature and humidity values as serial data. The sensor is capable of measuring temperatures ranging from -40°C to 80°C and humidity levels from 0 to 100 percent, with an accuracy of ±1°C for temperature and ±1 percent for humidity.

C. Flame sensor

The flame sensor serves the purpose of detecting flames or radiation sources within the wavelength range of 760 to 1100nm. It employs a YG1006 sensor, characterized by a high-speed NPN silicon photo resistor designed for infrared radiation detection.

Comprising an electronic circuit with a receiver, the sensor offers superior responsiveness and accuracy compared to conventional heat detectors, owing to its specialized mechanism.

Table 1. Measurement Unit

Sensors	Name	Symbol
Bluetooth module HC-06	Meters	[m]
Temperature	Celsius degrees	[°C]
Humidity	Percent	[%]
Flame sensor	Nanometers	[nm]

The values read by the sensors have a range of values for an optimal working environment. The HC-06 Bluetooth module has a range of approximately 8-10 meters, being perfect for this type of project. For the DHT11 temperature and humidity sensor, the range is between 20 and 60 degrees Celsius. The flame sensor can detect flames in the wavelength range of 760.

– 1100 nanometers. Small flames, like a lighter flame, can be detected at about 0.8m, and the detection angle is about 60 degrees, making the sensor particularly sensitive.

Table 2. Range of acceptable values

Parameter	**Min range**	**Max range**
Meters [m]	8	10
Temperature [C]	20	60
Humidity [%]	5	95
Flame [nm]	760	1100

Development environments

FreeRTOS is an open-source real-time operating system (RTOS) designed for embedded systems, specifically those with limited resources like microcontrollers and microprocessors. It offers a robust and flexible platform for developing embedded applications requiring deterministic real-time behavior, multitasking, and resource management.

FreeRTOS provides a preemptive, priority-based real-time kernel that ensures tasks are executed with deterministic timing. Tasks, representing individual application functions, can be dynamically managed, suspended, resumed, and deleted to optimize resource usage. The OS offers synchronization and communication mechanisms including for example semaphores, mutexes, queues, and event flags.

Communication protocols for wireless networks

Bluetooth protocol

Bluetooth operates within the 2.4 GHz frequency range, commonly utilized in wireless technologies, with a transmission power typically reaching up to 2.5 milliwatts. From a software standpoint, Bluetooth employs the Host Controller Interface (HCI) to establish communication between the Bluetooth host, including a laptop, and the core.

It also interfaces with protocols like Service Discovery Protocol (SDP), Radio Frequency Communication (RFCOMM), and Telephony Control Protocol (TCS) via the Logic Link Control and Adaptation Protocol (L2CAP). L2CAP is specifically designed to segment and reassemble large data packets for transmission to the baseband service via Bluetooth.

IEEE 802.15.1

IEEE functions as a networking standard that establishes the foundational framework for Bluetooth technology. The primary aim of this standard is to delineate specifications concerning the physical layer (PHY) and Media Access Control (MAC) for wireless connectivity among fixed or portable devices within a Personal Operating Space (POS).

3. SYSTEM IMPLEMENTATION

One of the initial setups adopted to facilitate Bluetooth transmission involved a rudimentary configuration utilizing a breadboard as the foundation. Integrated onto this breadboard were pivotal sensors including those dedicated to monitoring temperature, humidity, and flame detection. For the purpose of Bluetooth data transmission, the setup utilized an HC-06 module.

This module served as the intermediary conduit through which pertinent environmental data could be wirelessly transmitted to a compatible smartphone device. Subsequently, this transmitted data was made accessible for viewing and analysis via the interface of the phone’s serial monitor application.

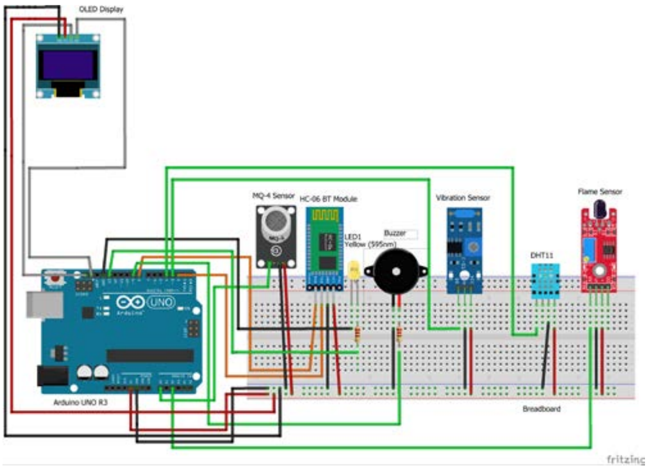

FIG. 1. Connection diagram

A. Sensor implementation

DHT11 temperature and humidity sensor

The sensor operates within a voltage range of 3.3V to 5.5V DC. It is imperative that the module adheres to voltage constraints, prohibiting the transmission of instructions beyondthe specified threshold.

In terms of communication and signal transmission, the DHT11 sensor utilizes a single bus communication protocol.

This bus architecture facilitates data exchange via a single dataline, enabling seamless communication between the microprocessor and the DHT11 sensor. Data transmission encompasses both integral and decimal components of relative humidity (RH) and temperature (T), each represented by 8 bits. The DATA pin of the sensor is connected to an I/O pin of the microcontroller unit (MCU), employing a 5K resistor for signal stability.

Flame sensor

The module offers dual voltage options of 3.3V or 5V, contingent upon the specifications of the development board. Communication with the development board is contingent upon the selected output mode, which can either be digital or analog. To fine-tune the sensitivity of the sensor, the LM393 comparator is employed.

In the case of digital output, connectivity is established by linking pin *D0* to the designated digital pin. Utilization of the *digitalRead(pin)* command enables users to ascertain thepresence of flame detection.

Alternatively, analog output provides valuable information regarding flame intensity, allowing for customized responses from the development board. Pin A0 is designated for connection to the analog pin.

For optimal performance and enhanced accuracy, preference is advised for analog output mode, complemented by the analog-to-digital conversion process.

B. Bluetooth module implementation

The Bluetooth module is supplied power from a +5V powersource. In order to enable its functionality, the Tx pin of the HC-06 module must be interconnected with the Rx pin ofthe Arduino microcontroller, while the Rx pin of the HC-06is coupled with the Tx pin of the Arduino board, employinga voltage divider. This voltage divider serves the purpose of converting the 5V signal emanating from the Arduino into a 3.3V signal, ensuring compatibility with the HC-06 module.

C. *Real-time performance analysis*

Using FreeRTOS, the following changes were made:

- The response time of both sensors exhibits enhancement, as evidenced by a reduction of 1 second in data acquisition when employing FreeRTOS, contrasting with lengthened data acquisition time in its absence.
- The adoption of FreeRTOS facilitates streamlined code organization through task management, fostering a structured and efficient execution framework.
- Task synchronization is achieved through the utilization of semaphores, ensuring harmonized operation among concurrent tasks. The incorporation of tasks introduces the concept of task prioritization, enabling the systematic arrangement of tasks. Priority is allocated to data transmission alongside the temperature monitoring task (Priority 1), followed bythe flame detection task (Priority 2).

4. THE PROPOSED SYSTEM DESIGN

System proposal

The project is committed to a comprehensive exploration and application of Bluetooth technology for transmitting gathered data. To accomplish this scholarly pursuit, the project intricately combines an Arduino development board with a Bluetooth HC-06 module.

This collaborative setup plays a crucial role in facilitating the smooth transmission of data collected by DHT11 temperature and humidity sensors, along with a flame sensor. The decision to utilize Arduino UNO modules is grounded in their inherent capability to connect with a wide array of peripheral devices via GPIO (General Purpose Input/Output) pins.

Additionally, the adoption of the Arduino IDE is essential for its scholarly accessibility and its ability to streamline programming processes, thereby enabling precise managementof the system's operational complexities.

Hardware design

This configuration was used in order to build a compact environmental monitoring system with uses like temperature and humidity measurement and flame detection [3].

In order to concentrate the ground and voltage pins, but alsoto keep the temperature as accurate as possible avoiding the Joule effect stimulated by the Arduino, we used the red and blue strips on the breadboard.

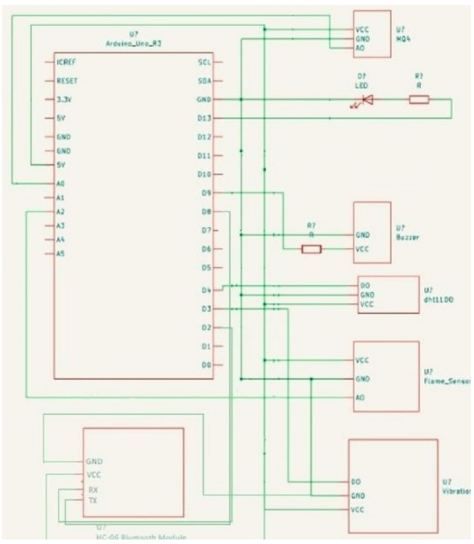

FIG. 2. Electric diagram

Software design

The firmware running on the microcontroller assumes responsibility for acquiring, processing, and transmitting sensor data. To manage tasks and ensure deterministic behavior, FreeRTOS is employed as the real-time operating system.

Additionally, a smartphone application has been developed for both Android and iOS platforms, allowing users to interactwith the system and visualize sensor data.

Incorporating appropriate libraries for individual sensors, the Arduino microcontroller, FreeRTOS, SPI communication, and semaphores has been essential.

Notably, special consideration was given to defining the pin and type of the temperature and humidity sensor separately. This was necessary due to the composition of the DHT11 mod- ule, which includes a thermistor for temperature measurement and a capacitive sensor for humidity measurement, requiringa specific library.

The DHT11 module is connected to pin 8 of the Arduino board. Furthermore, to enable communication with the Blue- tooth module, a SoftwareSerial object was initialized with Tx and Rx parameters, synchronized with the Arduino at a baud rate of 9600.

Monitoring commences once data transfer becomes avail- able via the Bluetooth module. Task creation utilized the xTaskCreate() function, with parameters specifying task name,FIFO size, and task priority.

```
xTaskCreate(
  TaskTrimiteDate
  ,  "task1"
  ,  128
  ,  NULL
  ,  1
  ,  NULL );
xTaskCreate(
  TaskTemperatura
  ,  "task2"
  ,  128
  ,  NULL
  ,  1
  ,  NULL );

   xTaskCreate(
  TaskFlacara
  ,  "task3"
  ,  128
  ,  NULL
  ,  2
  ,  NULL );

vTaskStartScheduler();
```

FIG. 3. Tasks creation

The xSemaphoreCreateBinary function is employed to in- stantiate a semaphore, a synchronization mechanism utilized for inter-task communication. Upon semaphore creation, memory allocation takes place within the FreeRTOS heap, enabling its subsequent utilization.

Following semaphore creation, the xSemaphoreGive (xBinarySemaphore) function is invoked to release the semaphore.Upon successful release, this function returns pdTRUE, indi- cating successful execution, whereas any encountered errors prompt a return of pdFALSE.

Subsequently, the xSemaphoreTake (xBinarySemaphore, 5) function is utilized to acquire the semaphore.

The parameter '5' signifies the duration, expressed in ticks, within which the semaphore is anticipated to become available [4]. Upon suc- cessful acquisition, this function returns pdTRUE; otherwise,it returns pdFALSE.

The interchange between states of the semaphore, from a state of 0 to being acquired by the xSemaphoreTake() function, is facilitated by the xSemaphoreGive() and xSemaphoreTake() functions. Should xSemaphoreTake() fail to return pdTRUE, the subsequent semaphore operations are not executed.

```
if (xSemaphoreTake(xSerialSemaphore, (TickType_t) 5) == pdTRUE)
  {
    sprintf(transmiteT, "Temperature:%d", temperatureData);// buffer

    xSemaphoreGive(xSerialSemaphore);
  }
```

FIG. 4. Semaphore

5. EXPERIMENTAL RESULTS

The experiments demonstrate the effectiveness and performance of the Bluetooth environmental monitoring system. The integration of multiple sensors allows for comprehensive environmental monitoring, with real-time data transmission via Bluetooth ensuring timely updates.

The utilization of FreeRTOS ensures efficient task management, enabling simultaneous execution of sensor reading tasks without interference. Furthermore, the custom phone application provides an intuitive interface for users to access and visualize sensor data, enhancing the system's usability andaccessibility.

Table 3. Comparison of execution times

Simulation	*Temp/Flame without FreeRTOS*	*Temp/Flame FreeRTOS*
1	5.09/5.11sec	179.10/179.07ms
2	5.15/5.12sec	179.09/179.10ms
3	5.01/4.98sec	179.07/179.06ms
4	5.30/5.26sec	179.07/179.14ms
5	5.50/5.55sec	178.99/179.13ms
6	4.89/4.94sec	179.12/179.16ms
Average	5.15/5.16sec	179.07/179.11ms

As evident in the system output, the serial monitor displays the time allocated for sensor measurements, facilitated by strategic task prioritization embedded within the system architecture. This intentional prioritization has led to a noticeable improvement in sensor responsiveness, significantly reducing the time required for data acquisition.

Specifically, the sensor response time has been shortened from an initial 5-second interval to approximately 200 milliseconds, highlighting a considerable enhancement in the system's operational efficiency and real-time data processing capabilities.

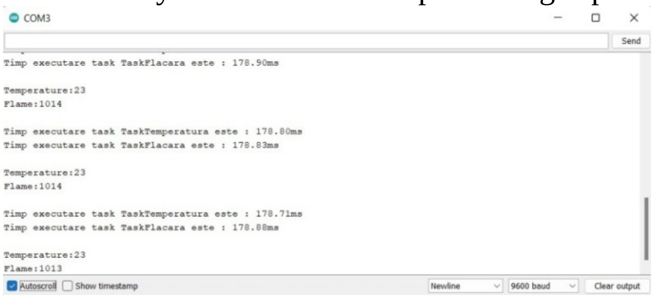

FIG. 5. Snapshot of Serial monitor

Table 4. Bill of materials for the project components

Nr.	Component	Cantity	Price
1	Arduino UNO R3	1	40 RON
2	HC-06 Module	1	30 RON
3	DHT11 Sensor	1	15 RON
4	Flame sensor	1	10 RON
5	Breadboard	1	20 RON
6	Jumper wires	10	15 RON
Total cost			130 RON

The phone in this case acts as a receiver, taking data from the Arduino board and displaying it on the display [6].

When the user presses the ”1” key on the phone, the mobile app displays the current temperature readings from the sensorsintegrated into the monitoring system.

Similarly, when the user presses the ”2” key on the phone, the app retrieves and displays the real-time flame value detected by the flame sensor, as shown in figure [6]

This functionality offers users immediate access to critical environmental data with just a few taps on their mobile de- vice. It enhances user convenience and accessibility, allowing individuals to monitor temperature and flame levels in their surroundings in real-time, without the need for additional hardware or complex interfaces.

Experimental studies

Study 1 - Normal Indoor Conditions (20°C, 50 % RH) This condition represents typical indoor environmental parameters, characterized by a temperature of 20°C (68°F) and a relative humidity (RH) of 50 %. It serves as a baseline for comparison against other conditions.

Location: Office Building

The office building serves as a representative indoor environment typical of many commercial establishments. It consists of office spaces, meeting rooms, and common areas where individuals work and interact daily.

FIG. 6. Phone app

Experimental Setup

- The environmental monitoring system is installed within a designated office space on one of the building's floors.
- Sensors are strategically placed to capture temperature and humidity levels representative of standard indoor conditions.
- Data collection occurs during regular office hours to capture fluctuations in environmental parameters throughout the day.

Study 2 - Elevated Temperature (30°C) and Humidity (70 % RH)

In this condition, the temperature is increased to 30°C (86°F), simulating warmer indoor environments, while the relative humidity is elevated to 70 %. This condition assesses the system's response to heightened thermal and moisture levels.

Location: Greenhouse

The greenhouse provides a controlled environment for cultivating plants, characterized by elevated temperature and humidity levels conducive to plant growth.

Experimental Setup

- The environmental monitoring system is placed within the greenhouse, positioned to capture temperature and humidity readings across different areas.
- Temperature is artificially increased to 30°C (86°F) using heating systems installed within the greenhouse.
- Humidity levels are raised to 70 % RH through misting systems or by controlling irrigation frequency.
- Data collection occurs over several hours to observe variations in environmental parameters under greenhouse conditions.

Study 3 - Low Temperature (10°C) and Humidity (30% RH)

This condition involves lowering the temperature to 10°C (50°F) and reducing the relative humidity to 30 %, mimicking cooler and drier indoor settings. It examines the system's performance under conditions of decreased thermal and moisture levels.

Location: Cold Storage Facility

The cold storage facility is designed to maintain low temperatures for preserving perishable goods like food and pharmaceuticals.

Experimental Setup

- The environmental monitoring system is deployed within the cold storage facility, situated among stored goods to monitor temperature and humidity levels.
- The facility's cooling systems are adjusted to achieve a temperature of 10°C (50°F) throughout the storage area.
- Humidity levels are reduced to 30 % RH using dehumidification systems installed within the facility.
- Data collection spans over an extended period to assess the stability of environmental conditions within the cold storage facility.

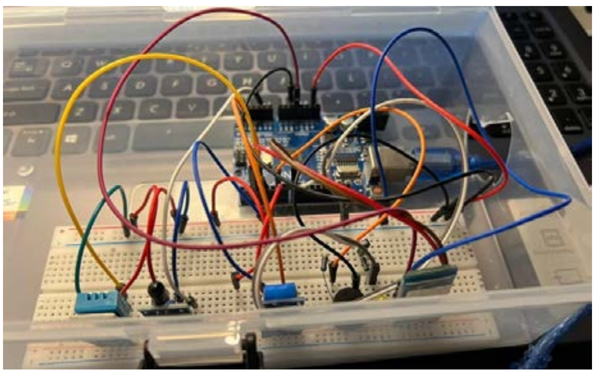

FIG. 7. Assembly

6. CONCLUSIONS

The presented Bluetooth environmental monitoring system represents a significant advancement in environmental monitoring technology. By addressing the limitations of existing solutions and introducing innovative features including sensor integration, real time task management, and user interaction capabilities, the system offers enhanced functionality, reliability, and usability.

Moving forward, continued research and development efforts can further optimize the system's performance, expand its capabilities, and explore new avenues for environmental monitoring and management.

In future iterations, the purpose is to downsize the device for seamless integration into smaller spaces. Additionally, plans involve introducing an environmental control mechanism, for example an automated sprinkler system activated in response to elevated temperatures. Moreover, there is a proposal to develop a mobile application enabling remote control of these regulatory devices.

This application is anticipated to incorporate features for sending email alerts in cases where users do not engage with the application or fail to receive notifications on their mobile devices.

Analyses and issues encountered

One of the challenges encountered was ensuring the accuracy and reliability of sensor readings, particularly during the calibration process. Variations in sensor performance and environmental conditions posed challenges in calibrating the sensors to provide accurate measurements consistently. Addressing these issues required careful calibration procedures and ongoing monitoring to identify and rectify any discrepancies in sensor readings.

There were also problems related to connecting the Bluetooth module to the existing application in the case of the iOS operating system.

In terms of compatibility, the iOS operating system supports a narrower range of Bluetooth protocols than an Android device.

Maintaining stable Bluetooth connectivity and ensuring reliable data transmission between the monitoring system and the mobile application presented challenges, especially in environments with high levels of interference or obstacles.

Issues like signal interference, range limitations, and packet loss affected the reliability of data transmission, requiring optimization of Bluetooth communication protocols and strategies for error detection and correction.

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CONSIDERATIONS CONCERNING THE PEOCESS OF OPERATIONALIZATION WITH AERONAUTICAL PERSONNEL OF THE FIRST AVIATION STRUCTURE EQUIPPED WITH MULTIROLE AIRCRAFT

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Abstract: *Romania's membership to the North Atlantic Alliance, the need to ensure interoperability with the aeronautical combat systems of the partners, the reality of equipping the Romanian Air Force with east technology , which could no longer carry out the planned peace service enforcement missions and air defense to crisis and war, imposed on the responsible factors the decision of purchasing the first aviation structure endowed with multirole aircraft. The process was also amplified by the evolutions that took place at the eastern border of NATO, including the borders of Romania, especially after the annexation, in 2014, of the Crimean Peninsula by the Russian Federation. Of absolute complexity and novelty, the acquisition, the training of the aeronautical personnel for the operation of new combat equipment and related activities have imposed on the structures and personnel involved in this process responsibility, innovation, devotion, the first and most important and consistent program of endowment of the Romanian Army being a recognized success of the Romanian Air Force and inspirational, for the subsequent acquisition programs of the national defense.*

Keywords: *multirole aircraft, acquisition, aviation, mission, operationalization, aeronautical personnel.*

1. INTRODUCTION

The motivation for writing this article consists of the presentation of the essential aspects that were highlighted in the modernization process of the Romanian Air Force with the first combat structure endowed with F-16 multirole aircraft, in order to achieve the operating standards of the armies of NATO member countries.

There will be highlighted the stages of the process of drafting the necessary legislative and regulatory framework, the difficulties of the initial training process, the recruitment and selection of aeronautical personnel according to the new architecture of framing the multirole aviation structure, and, completely different from the philosophy of personnel operation specific to the east fighter-type aircraft, training stages abroad and in the country, innovative solutions for the development of each stage according to the assumed level of ambition.

2. 53 SQUADRON IN THE FRAMEWORK OF PEACE AND WAR OF THE ROMANIAN MILITARY AERONAUTICS

The dismemberment of Greater Romania in the dramatic summer of 1940, through the abusive revision of the borders established and defended at the end of the War of National Enlargement, following the Soviet ultimatums at the end of June 1940, followed by the occupation of Bessarabia, Northern Bukovina and Herceland, the fascist Dictate of Vienna of 30 August 1940 and the annexation of North-West Transylvania from Hungary, the painful process concluded with the annexation of the Cadrilater from Bulgaria in early September 1940, reoriented the Romanian state policy in the direction of preparation, for the recovery of the lost territories, including the field of army.

Isolated internationally, with the imposition of the blockade by the great powers regarding the acquisition of weapons from abroad, Romania, thanks to its traditional relations with the British Empire, succeeded, in full painful outcome of international relations, in the acquisition of a modern long-range fighter squadron, equipped with the famous Hawker Hurricane aircraft, which was assigned to the 1st Fighter Flotilla, operating on Pipera airfield.

After some acquisitions of fighter aircraft from Germany Me 109 E, on June 1, 1940, within the 1st Fighter Flotilla was formed the 7th Fighter Group, consisting of the 53rd Fighter Squadron (equipped with Hawker Hurricane aircraft) and the 57th Fighter Squadron (equipped with Messerschmitt 109 aircraft).[5]

Captain aviator Ioan Rosescu was appointed to command the squadron, who handed over the command to aviator captain Emil Geogescu, considering the fact that he was a student at the War School. The members of the squadron had big names, future aces of military aviation or holders of prestigious orders, respectively lieutenant aviators Constantin (Bâzu) Cantacuzino, Toma Lucian, Horia Agarici, aviator adjutants Rădulescu, Pomut, Camenceanu, Cordescu, Popescu, Culcer, etc.

After executing specific stages of operationalization and integration into different combat structures, considering the exceptional technical and tactical characteristics of the aircraft, the 53rd Fighter Squadron was deployed on Mamaia airfield, for air defense of the Black Sea coast.

At the beginning of mobilization and deployment on the airfields used in the fight for the liberation of Bessarabia and Bukovina, the 53rd Fighter Squadron was redeployed on the Buzău airfield, in the afternoon of June 21, 1941, with the mission of protecting the bombing formations that were to start the air operation in the morning of June 22, 1941. [5]

Throughout the air campaign for the liberation of Bessarabia and the conquest of Odessa, the 53rd Fighter Squadron had cover itself with glory, the exceptional deeds of weapons and air actions executed by this elite structure of the Romanian aviation engaged on the front being recorded in detail in the diaries of operations of the 1st Fighter Flotilla and the Air Combat Group.

A summary of the most important dates: June 22 - the first day of battle and the first 4 air victories, June 23 - aviator captain Horia Agarci engages alone 6 Soviet bombers and shoots down 3, in the afternoon, redeployed to Mamaia, 2 air victories, June 24 - 4 air victories, JUNE 30, THE GLORY DAY OF THE SQUADRON - 10 AIR VICTORIES, July 1 - a probable air victory, July 4 - 3 air victories, July 10 - an air victory, July 11 - 2 air victories, July 13 - 2 air victories, July 14 - an air victory, July 15 - an air victory, July 22 - 2 air victories, July 23 - 3 air victories, August 28 - 3 air victories, September 6 - an air victory, September 8 - 2 air victories and one probable one, SEPTEMBER 12 - near Odessa, aviator captain Ioan Rosescu, returned to the squadron, shoots down 2 bombers, but crashes, with the plane on fire (the first and only loss of the 53rd Squadron), September 18 - the last air victory of the squadron on the Eastern Front.[5]

The balance of air victories reaches 52.1/3 of the total air victories obtained by the Romanian aviation in the Air Campaign for the liberation of Bessarabia and the conquest of Odessa (June 22 - October 16, 1941.

Until its deletion from the War Framework of the Romanian Royal Aeronautics, on December 15, 1944, the 53rd Fighter Squadron will participate with equally meritorious results in defending the national airspace against bombing raids by the Anglo-American aviation and will ensure the highly specialized pilot nuclei for the establishment of the first night fighter aviation structures of the Romanian military aviation.

This represents the ending of the exceptional episode of a fighting squadron, a structure that gave consistency to its history, the destiny, name and traditions of the 53rd Fighter Squadron being taken over, at the proposal of the Air Force General Staff / Personal Service and Mobilization, by the multirole combat squadron, equipped with F-16 aircraft, entered the Romanian Air Force on September 30, 2016.[6]

3. THE FOUNDATION AND ADOPTION OF THE DECISION-MAKING AND LEGISLATIVE FRAMEWORK OF “THE AIR FORCE MULTIROLE AIRCRAFT PROGRAM”

Since 2007, the leadership of the Romanian Air Force, analyzing the situation of equipping military aviation with modern type East technology, considered that postponing a decision on the modernization of the air fleet will stay against the fulfillment of the missions assumed within the North Atlantic Alliance and will endanger Romania's air defense in crisis and war.

The analysis is more justified by the fact that the resource of the MiG-21 LanceR, the multirole aircraft, which was in service, was going to expire in the perspective of 2015-2017, and the transition of aeronautical personnel to another aircraft category required a process of at least 2 years.

Overcoming the political-military decision barriers, the army leadership managed to promote the first decision of the Supreme Council of National Defense to endow military aviation with a modern multirole fighter aircraft. It was planned to replace the MiG-21 LanceR aircraft with a device compatible with NATO standards, which would ensure low operating and maintenance costs during the entire 20-year life cycle.

The political and governmental situation at the time of 2007, the international situation that did not indicate high risks and threats to Romania and the estimation according to which the accession to NATO in 2014 and the EU in 2017 did not require special efforts to equip the army, followed by the profound economic crisis of the following years, with defense budgets at the limit of survival, postponed the necessary decisions for the implementation of the CSAT Decision.

The new security context after 2010, the obvious attitude of reconsideration of the Eastern European borders by the Russian Federation, along with the sharp cooling of Russia-NATO relations, have also determined a new repositioning of abandoned steps to modernize the Air Force.

The analysis of the offers compatible with Romania's strategic interests as a NATO member highlighted the fact that the F-16 aircraft is in accordance with the operational requirements substantiated by the Air Force General Staff and ensures the acquisition at low costs and high reliability logistics possibilities.

The Supreme Council of National Defence, based on the arguments and proposals formulated, with **Decision nr. S-70 of 27.09.2012** approved *the Concept for the gradual achievement of air defense capability within the program "Air Force Multirole Aircraft"*. [1]

In application of the CSAT decision, the Romanian Parliament adopted **Law nr. 240 of 15.07.2013**, *for achieving the air operational capability included in Phase I of the initial transition phase of the Concept for the gradual achievement of air defense capability within the "Air Force Multirole Aircraft" program.* [2] By law, the Romanian Government awarded to the Government of the Portuguese Republic the contract for the purchase of 12 F-16 A/B MLU-M 5.2 aircraft from the surplus, the aircrew training service in Portugal and Romania, the technical assistance service, as well as logistic support elements. By law, the Romanian Government awarded to the Government of the Portuguese Republic the contract for the purchase of 12 F-16 A/B MLU-M 5.2 aircraft from the surplus, the aircrew training service in Portugal and Romania, the technical assistance service, as well as logistic support elements. Also, successive Letter of Offer and Acceptance (LOA) contracts, specific to the Foreign Military Sales Program - FMS, were awarded to the United States Government for the purchase of the necessary weapons and ammunition, as well as the completion of the initial logistic support package and the training service.

As a beneficiary of the program, the Air Force General Staff had a decisive role in carrying out, both in its initiation process, in the elaboration of the necessary basic and subsequent normative acts, but also throughout the development.

The measures taken at the level of the Air Force considered, besides the multitude of operational and logistical aspects and the analysis of all possibilities of providing aeronautical personnel with training series between 2014 and 2017, the establishment of target groups by categories of aeronautical personnel and the amplification of personal training, especially for knowledge of the English language.

It was concluded that the navigation personnel is motivated and well prepared to participate in the mission, being substantiated a coherent and absolutely necessary program for physical training and not only for this category of aeronautical personnel.

Complex problems were registered with the technical-engineering staff, being identified aspects that disrupt the optimal development of the training program abroad, such as:

- low selection base, given that most of the personnel had to be provided by the 86th Borcea Air Base, which, at the same time, carried out significant air police missions with the same personnel after the annexation of Crimea by the Russian Federation.
- insufficient knowledge of the English language at the level established by the contract, which implied the organization of training series of personnel in the English language centers of the Air Force or with personnel detached from these centers at the 86th Air Base in Borcea.
- and, last but not least, but of primary importance, the poor motivation of the technical-engineering personnel to participate in the mission, given the fact that the legislative system for the remuneration of the military personnel existing at that time determined the reduction of salary revenues for the personnel who was in the mission abroad.

In order to correct this situation, the Air Force General Staff/Personal Service and Mobilization initiated a working group at the Armaments Department, a structure responsible for carrying out the program, with the participation of all entities that had to ensure its deployment in optimal conditions.

The working group, following several rounds of analysis, submitted to the senior leadership of the army the report and the proposal for an emergency ordinance to correct the identified problems.

At the proposal of the Minister of National Defense, taking into account several considerations, including, *the absence of regulations regarding the status of Romanian personnel sent abroad for training on a type of combat technique with high complexity, the need to motivate personnel to participate in this type of mission and the negative consequences of not urgently promoting the normative act that ensures the regulation of the status of participating aeronautical personnel to the mission*, the **Romanian Government** adopted the **Emergency Ordinance nr. 37 of 18.06.2014**, *for Romanian personnel deployed to perform missions abroad in accordance with the provisions of contracts concluded under art. 1 lit. a) and b) of Law nr. 240/2013 for achieving the air operational capability included in Phase 1 of the initial transition phase of the Concept for the gradual achievement of air defense capability within the "Air Force Multirole Aircraft" program.* [3] The normative act regulated in a unitary concept:

- structurile, responsabilităţile şi procedurile pentru selecţionarea personalului în vederea participării la misiune;
- competența aprobării prevederilor de grad, studii, clase de salarizare şi coeficienţi de ierarhizare, precum şi armele şi specialităţile militare ale funcţiilor din statul de organizare constituit pentru perioada misiunii;
- the structures, responsibilities, and procedures for selecting staff to participate in the mission
- the competence to approve the provisions of grade, studies, salary classes and ranking coefficients, as well as weapons and military specialties of the positions in the organizing state established for the period of mission.
- participation in the mission by deployment on the approved organizing state.
- the ability to assimilate the functions of the staff of the organizing State established for the period of mission
- special financial rights during the period of deployment: salary, compensation, money for each day, food, transport.
- the destination of funds necessary for participation in the mission, namely the deployment of personnel, miscellaneous procurement, logistical support and operating expenses, personnel selection, disability and death insurance, medical evacuation, including of deceased personnel, development of relations with local military and civilian authorities
- signing the commitment with the post-mission obligations of the staff.

For the implementation of the adopted legislative framework, the **Order of the Minister of National Defense nr. M. 92 of 21.08.2014**, *regarding the preparation and execution of missions abroad in accordance with the provisions of contracts concluded under Law no. 240/2013*. [4]

During these stages, in advance, the Air Force General Staff through Personal Service and Mobilization developed, and after issuing Order M. 92, approved *the Operational Procedure for the selection for personnel participation in the mission*, with the thorough and coherent regulation of this complex process.

From a legislative and regulatory perspective, the process was over, but the actual development generated multiple challenges, successfully overcome by the responsible staff.

3. PHASE I OF THE TRANSITION OF THE "AIR FORCE MULTIROLE AIRCRAFT" PROGRAMME

The training of personnel for the operation of the F-16 fighter aircraft took place, according to the contract, at the 5th Monte Real Air Base in Portugal, started in September 2014, was completed in April 2017 and consisted, in a first stage, in the training of 88 military personnel, aeronautical personnel, pilots, technical-engineering personnel, mission planners, specialists in electronic warfare and metrology. During the preparation of the mission, the Air Force General Staff developed the training program for the personnel to be deployed for training abroad, designed the mission state and constituted the target groups that constituted the selection basis for participation in the mission.

The responsibility for selecting personnel to execute missions under contracts was assigned to the Armaments Department and the General Staff, through the Air Force General Staff.

According to the established coordination matrix, the Armaments Department had the competence to select personnel for the execution of technical representation missions and those in the metrological field, the Air Force General Staff having the responsibility of selecting the aeronautical personnel to frame the organization state of the multirole squadron - pilots, engineers, technical military foremen, flight mission planners.

Until their deployment to Portugal, the seafarers completed the initial physiological training course and the water survival course, and in the United States of America centrifuge training and testing to test the body's resistance to high overloads.

For the technical-engineering staff, the knowledge of English language was a very important criteria and sometimes difficult to achieve, inclusion in the target groups being achieved after an intense training process and testing the level acquired by the specialized center of the General Directorate for Human Resources Management.

According to the operational procedure approved by the Air Force General Staff, special selection committees were set up, with attributions to verify the fulfillment of the conditions for participation in the mission and to submit proposals with those eligible. The head of the Air Force had the competence to nominate the personnel, the proposals being subsequently submitted hierarchically to the Ministry of National Defense for the approval of the order of deployment.

The establishment of the first detachment was a challenge for the responsible personnel, given the novelty of the process, the deadlines from the moment of drafting the regulations to the actual deployment, but also some unforeseen situations regarding the last-minute medical fitness of selected staff, which implied their urgent replacement.

With multiple lessons learned, useful in approaching the later stages, the first detachment of 23 pilots, engineers, technicians and mission planners took off on September 30, 2014, with a C-130 Hercules aircraft from the 90th Air Transport Base "Comandor aviator Gheorghe Bănciulescu" and, after a 7-hour flight, landed at the 5th Monte Real Air Base in Portugal, the venue of the passage program.

Until April 2017, when the last detachment completed the training, several series were deployed to Monte Real Air Base, which went through courses specific to each specialty with different training durations, all pilots being trained at Combat Ready level or higher qualifications, being able to execute the full range of missions, according to the combat possibilities of the purchased F-16 aircraft, and the technical-engineering personnel were able to ensure the maintenance of the aircraft.

The absolute premiere was the very short acclimatization period for the flight on the F-16 aircraft, the first flight in simple command being executed by the first three pilots detached after less than two months of training, on November 26, 2014, captain-commanders Andrei Constantin and Micloș Cătălin and, very shortly, lieutenant commander Marin Mihăiță. The experience previously gained by operating the MiG-21 LanceR aircraft, the large number of flight hours accumulated on this aircraft, along with the participation in numerous exercises and missions both domestic and abroad.

After two years of training, on a sunny day of Thursday, September 29, 2016, the first six F-16 Fighting Falcon fighter aircraft purchased by Romania, inscribed with the numbers 1610 (double command, pilot captain-commander Cătălin Micloș-Miki, second cabin, Chief of Staff of the Air Force, Major General Laurian Anastasof), 1608 (single command, pilot Lieutenant Commander Cristian Cretu-Dodo), 1604 (single command, pilot lieutenant commander Lucian Tatulea-Tato), 1601 (simple command, pilot captain-commander Constantin Andrei-Zoro), 1602 (simple command, pilot captain-commander Mihăița Marin-Miță) and 1603 (simple command, pilot lieutenant commander Alin Cachiț-Pishta) took off at 08.00 local time, from the 5th Air Base in Monte Real, Portugal and, after a record flight of 4,000 km, with a stopover for recovery at the Air Base in Aviano, Italy, at 17.07 Romanian time, entered the national airspace, landing after a beautiful aerial evolution in formation on the new runway of the 86th Air Base "Lieutenant aviator Gheorghe Mociorniță" from Borcea.

According to the delivery plan, the other six purchased aircraft arrived in the country in series of three aircraft, on December 15, 2016, respectively 28.09.2017, and in accordance with the provisions of Law 237/2019, the 53rd Fighter Squadron was completed, starting with 25.03.2021, with five more F-16 aircraft.

4. CONCLUSIONS

The continuation of the Air Force endowment program with modern combat aircraft, at the operating standards of the contemporary theater of operations is a requirement of our days and of the current security context.

But the pertinent conclusions regarding this program, which we exemplify in summary, were presented by the head of the Romanian Air Force, Lieutenant General Laurian Anastasof, at the Open Day organized after the arrival of the first six aircraft at the 86th Air Base, on Saturday, October 8, 2016, attended by active, reserve and retired soldiers. lovers of military aviation: "The F-16 program is the most important endowment program carried out by the Romanian... which gives us, for Romania, the air defense capability we need... The platform is extremely complex, reliable, brings extra capability that we could hardly hope for... With this platform, we are all stronger! It is by far the most powerful weapon the Romanian Army has! They are by far the most invaluable people we have today in the Romanian Army, those who exploit them, pilots, engineers, technicians, insurance personnel, all those who make it possible to fly this plane... Let's bring history to where it is from, maintain tradition, have respect and appreciation for the past and continue giving 53 Squadron what it deserves, everything it needs, younger, newer and more beautiful, including a fourth-generation platform... Because that's what we've been able to do, to move from generation III to generation IV and to have created the prospects of hoping to move on to generation V... It is the moment when with a lot of diplomacy, with even more intelligence to bring combat aviation... where and where they deserve... The primary mission of 53 Squadron was, is and will be the defense of national airspace.”

The consequence of this programme? In the middle of November 2023, the F-16 centre at the 86th Air Base "Lieutenant Aviator Gheorghe Mociorniță" in Fetești, Borcea, was officially inaugurated.

The centre's inauguration is particularly significant, as it is probably the most important moment for the Romanian Air Force in 2023, a year in which three more F-16 aircraft have arrived and the Parliament has approved the purchase of F-35 Lightning II aircraft. Romania already has 17 F-16 Fighting Falcon aircraft purchased from Portugal, having signed the contract for a further 32 aircraft from Norway.

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THE FACTORS WHICH INFLUENCE MILITARY SYSTEM EVALUATION

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Abstract: *In an era where knowledge is diffusing at a relatively rapid rate, the nature and extent of the relationships enjoyed by a country's military forces with their counterparts abroad can become an important ingredient that enables more effective conversion of national resources into usable military power. Military-to-military relations come in various forms. At the simplest level, the presence of defense attachés in embassies abroad, functions as one conduit for monitoring new developments in technology, force structure, and organization. Participating in military education programs abroad and observing various foreign military exercises represents an interaction at a deeper, more significant level, especially if such participation is fairly continuous, is diverse with respect to the kind of instruction offered, and involves individuals who eventually return to postings in force training and combat development establishments back home. at the most sophisticated level, military-to-military relations take the form of combined exercises, combined training programs, and combined deployments for military missions.*

Keywords: *military system, national power, military capability, resources, infrastructure, evaluation.*

1. INTRODUCTION

Military capability represents the main point of a country's national power. Internal and external threats to states' security are not only common but also present. Thus, we can say that military capabilities are intended both for defence against potential internal or external adversaries and for offering leaders the possibility to follow and fulfil their interests, even against other concurrent entities.

So, state power is applied in various ways- internally and externally- by military power which also becomes a political instrument.

In conclusion, we can say that a country's national power should ideally represent the capacity of its military force to engage against its potential adversaries.

Admitting that this military force is capable to annihilate these adversaries, we should pay attention to the whole context in which this confrontation of forces could take place, in order to understand their rapport, and, should there be a power balance, to be able to identify, through a dynamic battle analysis, those circumstances and advantages which can be exploited in gaining success in a possible military confrontation.

2. MILITARY SYSTEM EVALUATION

In writing this paper I didn't intend to make a detailed analysis of military power evaluation as a result of military capability, but only as its resource. I have tried to contribute to identifying the necessary ingredients for creating an efficient force and understanding the way in which it could be theoretically conceptualized. So, the measures of ensuring military capability will be, as Stephen Biddle mentions, ”entrance measures”, that is what ” enters” in order to create an efficient national military capability. The attempt to compare the efficiency of some countries’ national capability cannot be interpreted as a possible analysis of military balance between them, the present study being just a prelude to the dynamic analysis of battle (Timothy D. Johnson, Winfield Scott: The Quest for Military Glory, 2018).

If we perceive military capability as a product of national power, it is necessary to understand that a country’s military organizations are the recipients of national resources generating combat capabilities. These will be efficient if they allow a country’s political-military leaders to impose their will against any adversary.

Reducing the logical framework of examining national power to the way in which national military units generate efficient military forces, we can ask ourselves whether it is enough if the army turns its available resources into military power and if this military power is also efficient. Of course, the resources that the militaries are provided with are very important and, the higher they are, the higher military efficiency is, but they are not enough. A clear military doctrine, adequate personnel training, good leadership and organization adapted to modern battlefield requirements are also necessary.

So, military power evaluation cannot be reduced only to accounting its components (personnel, weapons, etc) as it has been proved that big armies haven’t always been the most efficient. Thus, a state with a small army- Israel was victorious in last century’s wars, whereas the Chinese armed forces- perhaps the most numerous in the world- could not prove efficient outside their state’s borders. So, the real capability of a military force depends on much more elements than the state provided resources.

3. STRATEGIC RESOURCES

Any evaluation of a country’s military capabilities should have in view, first of all, the evaluation of financial, human, physical and technological resources that the state provides to its military institutions. At the same time, it is important to consider national performance and resilience, politico-military leaders’ ability to manage the present situation and foresee solutions to counteract the effects of any future threats to national security.

Viewed and analyzed on the whole, these aspects, which function interactively, can create a real image of the type of resources that the military personnel need.

Thus, in order to correctly measure a state’s national military power, it is necessary to obtain information about the following variable elements (Richard E.Beringer, Jones Archer and Hattaway Herman, *The Elements of Confederate Defeat: Nationalism, War Aims, and Religion*, 2019).

4. DEFENCE BUDGETS

The size of the budget assigned to defence is the main indicator of political leaders’ interest in increasing a state’s military capability. This information can be obtained from anaysing the percentage assigned to defence both from global public expenses and from the Gross domestic product (GDP)/ Gross National product (GNP).

Yet, for a better understanding and evaluation of the defence resources distribution, it is necessary to analyse the potential threats that the country is confronted to, the structure and real power of the country’s military institutions, as well as the way in which the militaries benefit from these resources: salaries, maintenance costs, military technology research and development costs. This information can create an overall picture of a country's military power. When part of this information is periodically reiterated, it could suggest certain tendencies in modifying military efficiency.

So, there are numerous ways of analysing and estimating a country's defence budget, but, time and again, for various reasons, a country's budget data are not available to the public, which makes it necessary to resort to analyses and estimations that could lead to a truthful conclusion. A method would be examinating a military's noticeable physical resources and calculating the taxes. Although we cannot categorise them as precise, these calculations can offer an approximate estimation of the state's commitment to support its armed forces and so they can be considered a first step in measuring its national power (Alice E. Carter, Richard Jensen. The Civil War on the Web: A Guide to the Very Best Sites, 2017).

5. MILITARY WORKFORCE

The second type of resource which contributes to increasing a country's national power is the military workforce. Its size and quality also offer a perspective on the dimension of national power.

The measurement of the military workforce requires, as a first stage of assessment, the examination of the total force, then its separation into its active and reserve components and their distribution among services. However, the detection of gross power alone is not enough for a complete picture, so, the facilities offered by open sources must be used in order to discover relevant information: the educational level of active and enrolled personnel, military equipment, as well as the ability to integrate and exploit the latest military technologies internationally.

At the same time, the way in which human resources are managed within the army can really contribute to building a more comprehensive picture of a country's military power . Here, we have in mind the existence of a military tradition, the extension of national societal divisions within the military system, the difficulties of integrating into the system according to gender, social class, race or ethnicity. Therefore, this is a valuable source of information that can contribute qualitatively and quantitatively, when assessing the basic nature of the military workforce and its potential in a possible conflict (John W. Chambres II. To Raise an Army, 2019).

6. MILITARY INFRASTRUCTURE

The third type of resource that has a significant impact on a state's military capabilities is its military infrastructure. This is, essentially, the physical infrastructure owned by a military force, commonly referred to as ”bases and facilities”. In addition to facilities for accommodating military personnel and equipment, this category includes training and testing facilities, medical facilities, warehouses, etc. the extent and quality of these facilities can contribute to military capability development.

The ability of the military infrastructure to support soldiers provides, of course, a valuable tool for assessing a state's military power. In this regard, in order to analyze, for example, a country's air power, the information on the number of air bases in relation to the existing air forces, the type of protection (active and passive) offered to aircraft and the airfield, the level of protection offered to its elements (checkpoints, communication centers, fuel-lubricant depots, ammunition, etc) must be used.

Of course, all these resources can be considered components of a country's military capital and can contribute to its military effectiveness, but for a more accurate assessment of their value, it is necessary that all information about them be corroborated and interpreted not only synthetically but also analytically.

7. INDUSTRIAL DEFENCE BASE

Another resource that determines a country's military effectiveness is the industrial defence base, more precisely the industry involved in the production of technologies and military tools. This depends on the allocations from the country's defence budget, on the funds needed for the production of these goods for military use, on which the country, in turn, depends to ensure its military power.

For a generic assessment of the industrial defence base, one could resort to the classification according to the quality and degree of autonomy of a country's production capability: large and small weapons, non-lethal but strategic products, support consumables (John W. Chambres II. To Raise an Army, 2019).

Of course, very few states, especially those with a strong, technologically advanced industry, can achieve full autonomy in the production of military equipment, most countries being forced to more or less resort to imports– which ultimately means certain vulnerability.

Obtaining relevant information about the industrial defence base structure and quality contributes not only to creating an image of an army's own capabilities, but also to revealing its vulnerability when the information about dependence on foreign suppliers is relevant.

8. INVENTORY AND COMBAT ASSISTANCE

A country's military inventory and combat support capabilities are as important as any other category of its military power. Therefore, obtaining intelligence about some countries' military inventories has been and will continue to be one of the main objectives of the intelligence community. Together with the intelligence about military workforce, the intelligence about the military inventory and the combat support capabilities will reveal a country's real military capability.

In this regard, it is the intelligence community's responsibility to collect intelligence on the number of tanks, artillery pieces, ships and fighter jets and other military equipment held by different countries. Possessing this intelligence can help shape both the defensive and the offensive capabilities of a country (John W. Chambres II. To Raise an Army, 2019).

However, it must be borne in mind that war is a constantly changing phenomenon, especially in terms of its nature and conduct, and especially the forces and available and used means. Hence the reluctance to collect real data about the weapons and combat facilities of potential opponents, about the different categories of stocks and their combat support capabilities.

CONCLUSIONS

Strategic resources are essential for a country's military capability, but they are not enough to create a military force capable to respond efficiently to any type of threat. These resources need to be assessed, converted into military force and used as such on the battlefield.

Successful conversion of these resources into an efficient military capability is undoubtedly a real test of military leadership quality, but, unfortunately, success in this endeavour is often conditioned by factors, structures and entities that go beyond the military institution itself.

Of the many factors that influence the militaries' ability to turn resources into operational capability, the following may be the most important:

(1) Threats to national security that may frequently change, and thr strategy developed and adopted to deal with them.

(2) The structure of the civil-military relationships, including military access to the decision making process which could enable them to understand change in major national objectives, to support the allocation of additional resources and gain the freedom to operate in order to transform them into efficient operational capability.

(3) Military relations with foreign armies, which facilitates access to intelligence about other military forces.

(4) The doctrinal nature, training and organization within a force, which allowsgross military resources to support the combatant forces efficiently- from an operational and a practical point of view.

(5) The potential and capacity for innovation, which gives a military force the oportunity to cope with it ever-changing strategic and operational missions, while seeking solutions to keep it afloat before potential adversaries.

All these variables condition a country's military leadership ability to achieve effectiveness in the event of an armed conflict. Consequently, understanding how these qualitative factors affect military capability is important in order to analyze one's own national power and the potential adversaries' national power.

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FUNDAMENTAL ASPECTS REGARDING THE FUNDING POTENTIAL OF THE MINISTRY OF NATIONAL DEFENSE THROUGH EUROPEAN PROJECTS

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Abstract: *This article will present the theoretical aspects and the possibility of financing the Ministry of National Defence through European funds.*

At the same time we will highlight the fundamental aspects of financing public institutions through the use of European funds.

The scientific communication is based on pragmatic approaches that will shape the financing of public institutions, starting from the eligibility of a project to the use of the budget and the completion of the project. It will look at how to implement the investment budget from European Union resources.

In recent years, the Ministry of National Defence has faced significant challenges in securing adequate funding to modernize the armed forces and address emerging security threats. European Union (EU) funds have emerged as a potential source of funding for Member States' defence initiatives.

Keywords: *funding, non-reimbursable funds, European Defence Fund, Operational Programs.*

1. INTRODUCTION

The topic of this paper deals with them modalities of financing public institutions through European funds and how to implement them. The methodology of the paper is based on pragmatic approaches to eligibility and obtaining European funds, and it is believed that these approaches will be able to bring to the forefront the financing of public institutions through investment funds that are made available by the European Union.

The effective concepts of implementation of European funding were exemplified by Michael Bauer and the principles highlighted by him underlie the implementation and eligibility of a project financed by European funds.

Therefore the possibility of financing the Ministry of National Defence through European funds is a topical issue and is important to be explored. The defence sector has played and continues to play a vital role in protecting national security.

The defence sector plays a crucial role in ensuring the security and stability of nations. For example in space domain, the *„race to win supremacy in this new field of military actions pushed economic and military powers of the world to allocate huge amounts for investment in equipment and technologies needed to dominate space"* [2]. However, modernising and maintaining an effective military force requires substantial financial investment. Romania, like many European countries, faces the critical task of securing defence funding. With limited national resources, exploring alternative financial channels, such as European funds, has become an imperative.

Access to funding through European non-reimbursable projects requires compliance with specific EU criteria.

The Ministry of National Defence must ensure eligibility by aligning their defence initiatives with EU strategic priorities, respecting public procurement regulations and adhering to European industrial competitiveness policies.

Therefore, by meeting these criteria, defence institutions can maximise their chances of receiving financial support from European programmes.

The European Defence Fund is the EU's cornerstone initiative for strengthening defence cooperation and reinforcing Europe's defence industry.

2. THEORETICAL CONCEPTS CONCERNING THE FINANCING OF INSTITUTIONS BY MEANS OF EUROPEAN FUNDS

The generalised concept of "European funds" actually designates the instruments through which the non-reimbursable financing allocated to the Member States of the European Union (EU) will be made, which will reduce certain gaps that are subject to the economic and social development of the European Union states. These funds are managed in a joint manner by the European Commission and each individual Member State.

For Romania, the European Structural and Investment Funds, found under the acronym of European Structural and Investment Funds (ESI), are the main funding resource of the Operational Programmes that have as their main goal the implementation of economic and social cohesion policies at national level.

The types of European Structural and Investment Funds are classified as follows:

- European Regional Development Fund;
- European Social Fund;
- Cohesion Fund;
- European Fund for Agriculture and Rural Development;
- European Fund for Fisheries and Maritime Affairs.

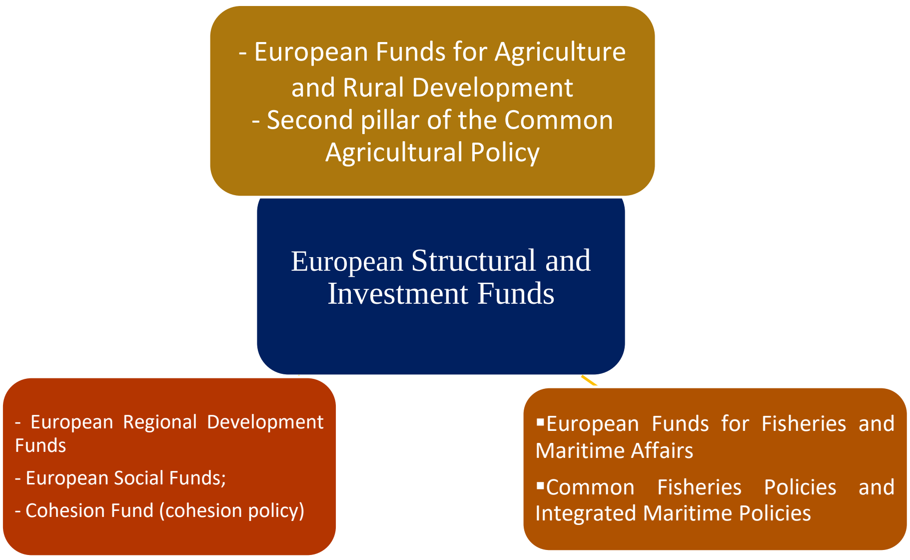

FIG. 1. Classification of European Structural and Investment Funds

The European Parliament's Committee on Regional Development has drawn up a plan highlighting best practices in different policy areas and removing obstacles in the use of Structural Funds.

This report is intended to highlight best practice as a way of overcoming certain obstacles and the benefits that come from using EU cohesion funds.

In the context of the report, no clear reasons are given for bringing definitions of "best practice" to the fore, but it does urge the need for a clear definition.

Subsequently, in the guide for the preparation of projects financed by European funds, some definitions have emerged and what the process it goes through entails.

A simplified definition of a project is that it is a “temporary effort to create, with limited resources, a unique product or service”[8].

Projects are therefore processes that involve the following:

- The point from which an individual ,, will throw" something, towards a target;
- Eliminating a problem that has been identified and changing the situation;
- The existence of goals that should be possible to achieve;
- A solution to solve a specific problem;
- A beginning and an end, which will take place in one place;
- Involvement of certain skills based on planning and implementation;
- The existence of a team, whose main objective is to aim for the good of an organization or community;
- A number of risks and uncertainties.

Therefore, in order to make management activities more effective in programs and projects, the following aspects of the design and implementation processes should be considered.

The conditions for the preparation and implementation of projects financed by European funds are based on the following principles:

- Objectives must be realistic and clear for both projects and programs;
- Quality factors", which have the main role of reinforcing the long-term benefits of the project;
- Contribution to and consistency in the overall achievement of the European Union's objectives through projects and programs.

3. PRINCIPLES UNDERLYING PROJECT CYCLE MANAGEMENT

Project Cycle Management can be defined as a possible integrated approach to planning, design and management. This theory can ensure that the underlying principles of this approach are taken into account in a methodical way, at each stage, throughout the life of the project.

Project Cycle Management takes into account the broader spectrum of external cooperation, which is promoted within the European Union, through poverty reduction as its main objective.

Taking into account the strategic areas of the Maastricht Treaty, the following aspects emerge:

- Development is a lasting one, especially if it promotes equitable development on the side of investment and policies dealing with labor, social development and environmental protection;
- Integration into world economies through support;
- Fighting poverty.

Therefore, the purpose and impact, given by a program is more comprehensive thanin the case of an individual project.

Projects and programs are different in terms of the scale of the resources to be used, in terms of their time scale, but also in terms of the formulation of objectives, management structures and the well-defined role that project team members must play.

The projects, which are individual, will be part of cyclical projects, whereby each term is intended to lead to the long-term achievement of the priorities set out in organizational or institutional strategies.

Project Cycle Management, found under the acronym PCM, is considered an integrated approach to project planning, design and management.

This approach comes with the following six stages of a project cycle approach:

- programming, being the phase in which the principles and the progress that will bring the collaboration with the European Union to a successful conclusion are established in close connection with the Government;

- identification, at this point specific ideas, which are related to programs and projects, are identified and reviewed within the framework established by national strategic documents;

- appraisal, during this phase the project idea will be translated into a proposal and the key aspects of the project will be analyzed in detail;

- financing, this is the phase in which a funding proposal is made and then submitted for evaluation to the appropriate bodies and commissions. Following this phase it is decided whether the project receives funding or not;

- implementation consists of the efficient implementation and completion of all actions in the most favourable conditions, in accordance with the initial plan, using the necessary and planned resources, which will generate the expected results in order to achieve the project objectives;

- evaluation (Evaluation), the role of evaluations that can determine the relevance and achievement of all objectives, project effectiveness and efficiency, impact and sustainability [6].

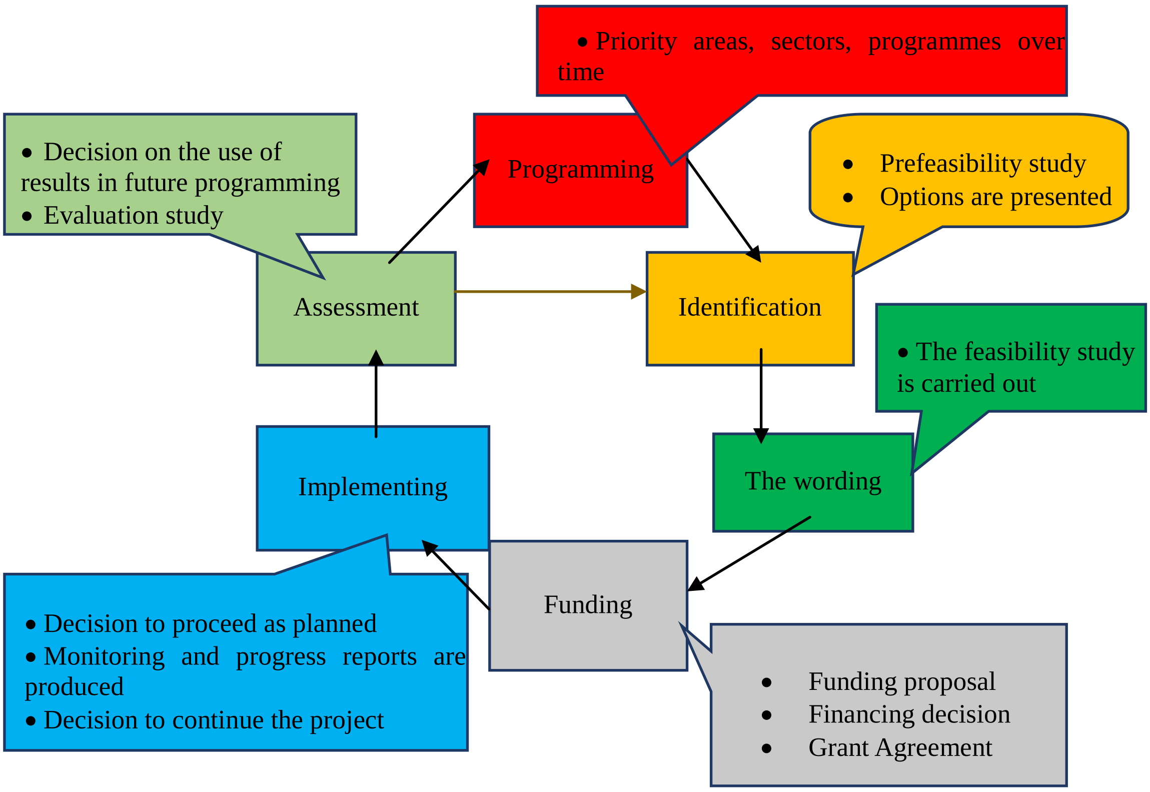

FIG. 2. Project life cycle: documents and decisions

The evaluation phase can also go through other stages:

- during the implementation phase, through mid-term evaluations, at which point certain decisions can be taken, such as whether to continue, change or cancel the project;
- at the end of the implementation phase, at which time the final results received are established and the results of the main objectives are checked;
- at the end of the project, ex-post evaluation and its main objective is to analyze the main consequences of the project and can be used in future projects.

The underlying principles of the ECHP are as follows [1]:

- to systematically respect the major priorities and policies of the European Union;
- implementation and project design will be based on clear and realistic objectives;
- relevance, feasibility and sustainability of the projects financed;
- consultation and involvement of stakeholders throughout the project;
- establishment of key factors by which the project starts.

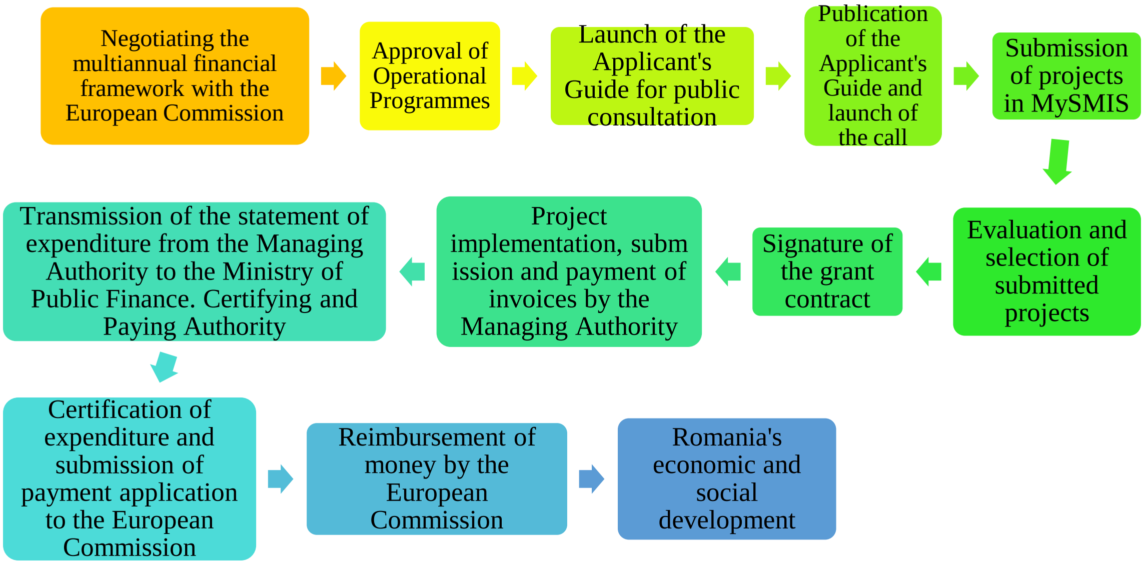

FIG. 3. The European Money Trail

Quality factors that underpin the sustainability of the project and have a positive impact:

- participation and involvement of beneficiaries in the design and implementation of the project;
- securing political support from representatives of authorities, both local and central;
- use of appropriate and adequate technologies;
- adapting the project strategy to the specific socio-cultural aspects of an area;
- systematic application of equal opportunities principles and practices;
- protection of the environment;
- managerial and institutional development;
- financial viability to be introduced in the project for the target group.

4. **ADVANTAGES, CHALLENGES AND OBSTACLES OF FINANCING THE MINISTRY OF NATIONAL DEFENCE FROM EUROPEAN FUNDS**

Not having the possibility to finance all its investments for the modernisation of the army, the financing of these major programmes through European projects comes with a number of advantages, but at the same time, challenges and obstacles will arise, leading to the end.

1. These advantages are as follows:

Increased modernisation opportunities: European funds offer the potential to improve the modernisation process of the Romanian Army. These funds can be used to acquire advanced technologies and equipment, improve infrastructure and build the capabilities needed for contemporary warfare.

Reduced dependence on the national budget: funding obtained through European channels could ease the burden on the national budget, allowing increased spending in other areas such as education, health and social welfare. This could contribute to the overall development of society.

Promoting European security integration: Financing the Ministry of National Defence through European funds can stimulate better collaboration and integration between EU Member States. This allows Romania to align its security interests with those of its European partners, ensuring collective strength and security in the region.

Improved interoperability: securing European funds can facilitate participation in multinational defence projects, encouraging greater interoperability with other EU countries.

This interoperability is crucial for joint military operations and enhances Romania's ability to contribute effectively to NATO and EU missions.

2. Challenges and obstacles that the Ministry of Defence National Defence will encounter during these contracts are:

Competition for funding: the availability of EU funds for defence purposes subject to competition from various sectors, including infrastructure, transport and R&D. The Ministry of National Defence needs to create convincing proposals highlighting the crucial role defence plays in regional security and stability.

EU rules and criteria: Accessing EU funds Romania must demonstrate a strong strategic vision, financial responsibility and prioritisation of defence needs in order to secure funding.

Therefore, through European non-reimbursable funds, the Ministry of National Defence has developed and is developing a series of vital projects on different axes, such as [11] :

- Through Priority Axis 3, ,,Public Buildings" , there have been Rehabilitated the infrastructure of 6 buildings within the Ministry of National Defence, namely [11]:

- a series of works were carried out to improve the energy performance of the building, with the final result of reducing energy consumption, in Pavilion 31 of the 329 Boboc barracks. This had a total value of 23.13 million lei, of which the MApN contribution was 16.96 million lei;
- the thermal rehabilitation of pavilions C4 in barracks 3416 Constanta and pavilions D, D1, D2 and D5 in barracks 1369 Constanta was carried out. The total value of this project was 32.58 million lei. At the same time, for the rehabilitation project of pavilions D, the percentage of eligible expendituresis 55.92%.

In view of the modernization that the Ministry of National Defence is undergoing, the MApN Committee for the Organization and Coordination of the process of attracting non reimbursable European funds has initiated a series of projects to access European funds under the National Recovery and Resilience Plan (PNRR), in most of the MApN's areas of interest.

Therefore, MApN has submitted several projects for the rehabilitation and modernisation of the wards of military hospitals in Romania, through Component 12 - Health and Component 5 - Wave of Renovation, and the total value of these wards is about 120 million euros, and the deadline for completion of the works financed by PNRR is 2026.

Through the eligibility simulation, the MApN Committee, together with the Directorate of Domains and Infrastructures (DDI), has prepared applications for funding on another axis of the PNRR, which will have as its primary objective to rehabilitate all public buildings, and the total value of the investments is about 12.4 million euros.

In this regard, we appreciate that it is necessary for the Ministry of National Defence to apply effective financial management, which is considered a priority for achieving objectives and fulfilling specific missions, and also *„economic and financial management represents a segment of general management, an extension of it into the economic and financial area of the organization”* [3].

CONCLUSIONS

We can conclude that the approach to projects financed by structural funds is particularly complex, with numerous implications in several areas (social, economic and geopolitical).

These funded projects are intended to enable all institutions to achieve a multitude of strategic objectives, more than they could have achieved through their own budget or from the state budget.

One aspect to bear in mind when financing projects through European funds is the social and economic impact they will have in the future, i.e. how the situations of the people who will benefit from the financing of the projects will improve and how the social environment will become.

Securing funding through European funds provides Romania with an opportunity to strengthen its defence capabilities, increase interoperability with European partners and be able to promote regional security integration. By actively engaging in European defence initiatives and developing strategic partnerships, Romania will be able to present convincing proposals and meet the challenges inherent in accessing European funds.

It is essential for Romania to priorities the needs of the defence sector and to pursue funding avenues that contribute to national security and the wider European security architecture.

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THE IMPACT OF EMERGING TECHNOLOGIES ON SUPPLY CHAIN MANAGEMENT IN THE MILITARY ORGANIZATION

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Abstract: *This paper provides a general exploration of the transformative impact of emerging technologies on supply chain management in the military organization. It highlights the integration of advanced technologies such as artificial intelligence (AI), blockchain and autonomous systems, highlighting their profound effects on improving operational efficiency, security and real-time supply chain management. The study assesses the balance between improved logistics capabilities and the complexities introduced by these technologies, including concerns about dependency and cyber security.*

Through a technological innovation perspective, the paper proposes a conceptual framework of military supply chain management, proposing a future-oriented strategy for supply chain management in the military organization in an adaptive and resilient manner. This research is essential in understanding the synergy between cutting edge technology and military logistics in the modern era.

Keywords: *management, supply chain, artificial intelligence, emerging technologies, military organization*

1. INTRODUCTION

In the ever-evolving landscape of global military operations, the effectiveness and resilience of supply chain management are critical factors that determine the success of military efforts. The research analyzes the paradigm shift that military logistics has undergone following the emergence and implementation of emerging technologies within it. Traditional logistics frameworks, once constrained by manual processes and procedures, limited real-time data, are now being revolutionized by adopting advanced technological solutions. The introduction of artificial intelligence (AI), blockchain technology and autonomous vehicle systems, as well as automated decision-making processes, has not only improved the operational efficiency of military supply chains, but also redefined the paradigms of security, accuracy and speed in logistics management.

The significance of this development cannot be underestimated, as military logistics forms the backbone of any military operation, ensuring the timely delivery of essential resources, from weaponry to basic necessities for military personnel. Integrating these cutting-edge technologies into military logistics is not just a matter of modernizing systems, but a critical shift toward a more agile, secure, and cost-effective supply chain capable of meeting the dynamic demands of modern warfare. However, this technology integration also brings new challenges, including managing complex systems, the need for specialized training, and concerns about cybersecurity and technology dependency.

The paper aims to provide an analysis of the impact of these emerging technologies on military logistics management. The objective is not only to understand how technology is reshaping military logistics, but also to forecast future trends and challenges in this field through a bibliometric analysis.

In addition, it is intended to explore the strategic implications of these technological advances on military competitiveness and readiness. It investigates how the integration of these technologies can lead to a paradigm shift in the power dynamics of military conflicts, where logistical prowess increasingly dictates operational success. Furthermore, the study explores into the ethical and geopolitical considerations surrounding the adoption of such technologies, highlighting the need for a balanced approach that protects both efficiency and integrity in military operations.

2. CURRENT STATUS AND TRENDS IN THE FIELD OF RESEARCH

The field of military supply chain management has been the subject of extensive academic scrutiny and research, thus reflecting its critical role in ensuring the effectiveness and efficiency of military operations. This chapter presents a bibliometric analysis of the existing literature on military supply chains with the aim of systematically mapping the academic landscape and identifying key trends, thematic developments and research gaps in this field. As global military strategies increasingly depend on the robustness and agility of supply chain systems, understanding the amplitude and depth of academic research in this area becomes imperative.

Bibliometric analysis, a quantitative approach to literature review, provides a unique perspective to view the field of military logistics. By analyzing data from a multitude of research papers, this chapter uncovers patterns and relationships, such as the most influential authors, essential publications, and dominant research themes that have shaped the understanding of military supply chains over time. In addition, it aims to identify emerging topics and technologies that are gaining ground in the academic community, thereby providing insights into future research and development directions.

The focus on military supply chains is particularly relevant at a time when technological advances, geopolitical shifts, and evolving military doctrines are continually reshaping the logistics landscape. This bibliometric review not only serves as an essential tool for academics and researchers to navigate the vast literature, but also assists military strategists and policy makers in understanding the historical context and future trajectories of supply chain management in military.

Using the search term: subject: ("military") AND ("chain of supply ") in the Scopus database resulted in a total of 985 scientific papers, including literature from the beginning of the 21st century.

Bibliometric analysis applies mathematical, statistical, and visual methods to summarize research patterns and trends in scientific publications. Using the metadata from the Scopus database and the visualization software VOSviewer, a map was created that illustrates the structure of the knowledge domain. Co-occurrence, a method frequently used in scientometric analyzes for various purposes such as co-authorship and co-citation, was applied. From the sample of examined articles, which includes 6982 keywords, 677 keywords with more than 3 co-occurrences were selected, resulting in 23031 connections in 6 clusters. These connections are represented on the map by circles, the size of which varies according to the frequency of occurrence, and they are connected by lines that highlight the strength of the connections between them.

This map created using VOSviewer illustrates the complex relationships between various keywords in the scientific literature related to military supply chains and artificial intelligence.

We note that the theme of "supply chains" is central and interconnected with a variety of relevant topics, indicating its transversal importance in several fields of study. Also, the term "supply chain management" stands out as a major node, underlining the strong focus on optimizing and effectively managing supply chains.

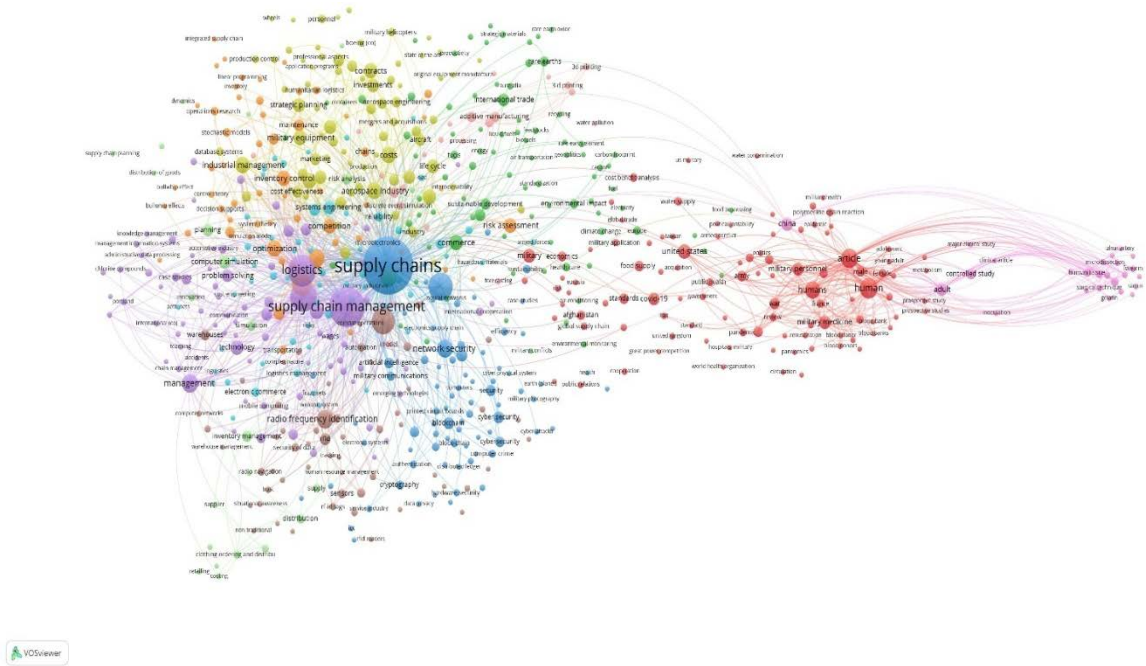

FIG. 1. Map of keyword co-occurrence networks

The color and size of the nodes represent the frequency and importance of each keyword, and the lines between them illustrate co-occurrence relationships. For example, we can see that there is a substantial discussion around "network security" on supply chains, technologies such as "Cryptography" and aspects related to "sustainability", an increasingly accentuated and recurrent trend in the last period in university and business environments [1].

We also observe the trends towards a management of logistic support lines focused on sustainability, green energy and attention to the environment and social not only in the civil and business environment, but especially in the military [1], [8].

The dense interconnections and diversity of terms reveal that supply chain research is interdisciplinary, involving aspects of engineering, technology, management, and even public health, reflecting the complexity of modern realities in industry, business, and the military.

Large and well-connected nodes represent central and often discussed concepts such as "logistics", "industrial management", and "optimization", suggesting that these are critical aspects in study and application supply chains. On the other hand, clusters of smaller or less connected nodes may indicate research niches or emerging topics.

This map can be used to identify dominant trends and guide future research and development in supply chain management, highlighting areas that need more attention and possible cross-disciplinary connections that can be exploited for innovation.

It also presents a clear visual perspective on how different topics are interconnected, giving researchers and practitioners a foundation to build on the fertile intersections between diverse fields of interest.

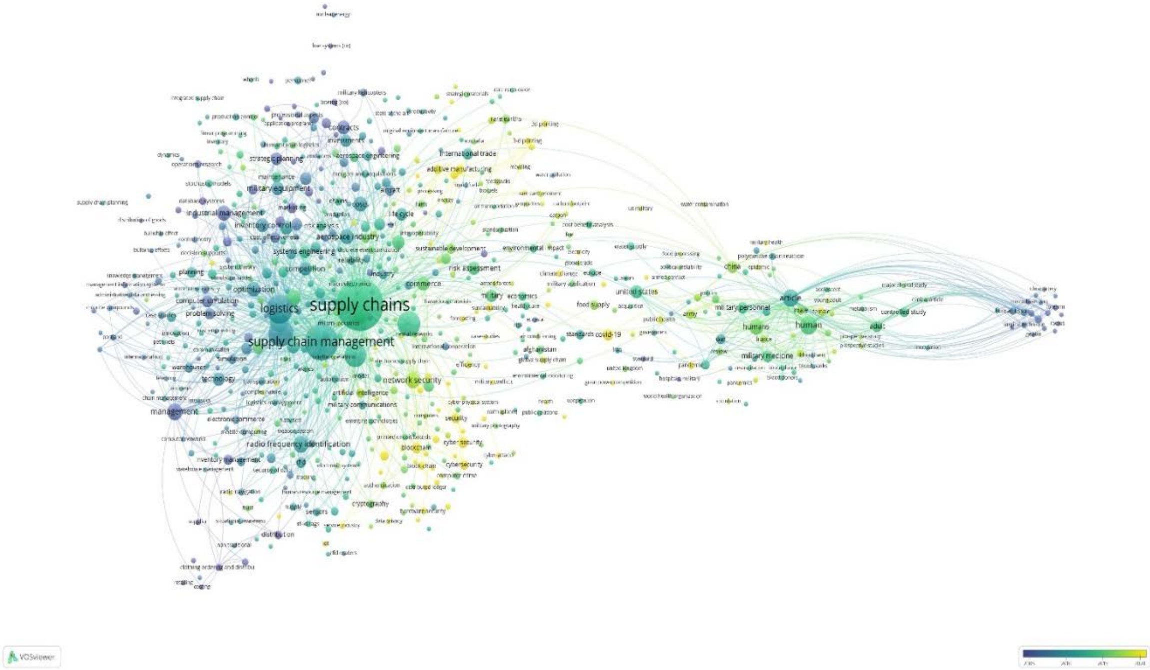

FIG. 2. Map of co-occurrence networks - temporal perspective

The timelines at the bottom of the map suggest the evolution and growth of interest in certain topics over time. For example, we can infer that interests have shifted from traditional supply chain management topics to topics dealing with the impact of emerging technologies and global issues such as pandemics, renewable energy issues or sustainability, signaling changes in the real world and how they influence academic research.

At the same time, performing an analysis of the co-occurrence of key words, we arrived at the following graph, see Fig. 3. From the results obtained from the number of occurrences of the keywords, we will present the first 20 words with the highest number of occurrences in the analyzed sample.

Among the first words in terms of number of occurrences we have " supply chains " with 355 occurrences and " supply chain management " with 177 occurrences. The "logistics" domain proves its importance, being the basic domain of the supply chain. In the same way, the word "military operations" implies the vision of an interconnected whole that is to be represented using models and the application of artificial intelligence techniques. The words "artificial intelligence" (83 occurrences), "decision-making" (51 occurrences), and "network security" (34 occurrences) are core terms in current research on the implementation of emerging technologies in the military environment.

At the end of this chapter dedicated to the bibliometric study, we can affirm that the in-depth analysis of the specialized literature, carried out through the prism of the bibliometric and scientometric methodologies, offered a comprehensive perspective on the current contours and the evolution of the dynamics in the studied field. Visualization tools, such as VOSviewer, allowed not only to map the relationships between different concepts and key terms, but also to observe how these interconnections developed over time, reflecting paradigm shifts and the advance of knowledge.

By identifying thematic clusters and evaluating the co-occurrence of keywords, we were able to detect both well-established domains and emerging niches, thus opening new horizons for future research. This analysis has been particularly valuable in highlighting areas where scholarly dialogue is most intense, as well as pinpointing areas that, to date, have been less explored.

The bibliometric study contributes significantly to the understanding of the structure and trajectory of research in our area of interest, enriching the theoretical foundation and indicating future directions of investigation.

No.	*Key word*	*Co-occurrence*	*Number of links*
1	Supply chains	355	2549
2	Supply chain management	177	1397
3	Logistics	107	902
4	Military operations	94	809
5	Artificial intelligence	83	502
6	Military applications	76	562
7	Decision making	51	515
8	Human	46	513
9	Article	40	477
10	Radio frequency identification (rfid)	38	327
11	Management	37	423
12	Military logistics	34	211
13	Military supply chains	34	232
14	Network security	34	298
15	People	32	358
16	Industrial Management	31	303
17	Aerospace industry	30	240
18	Optimization	30	261
19	Costs	29	218
20	Inventory control	26	235

FIG.3. Co-occurrence of keywords

3. THE USE OF EMERGING TECHNOLOGIES WITHIN THE MILITARY ORGANIZATION

One of the main areas of activity and interest in the new era is the use and implementation of blockchain technology in logistics processes. Blockchain is a distributed ledger technology, best known for its role in underpinning digital currencies such as Bitcoin. It provides a secure and decentralized way to record transactions and information in a digital blockchain, where each block contains a number of transactions. Key features of blockchain include:

- Decentralization: unlike traditional systems where data is stored centrally, blockchain distributes data across a network of computers, thus eliminating the need for a central authority and reducing the risk of data manipulation or corruption.
- Security: Each block in the chain is encrypted and linked to the previous block by a cryptographic process, making it nearly impossible to retroactively change records without affecting all subsequent blocks.
- Transparency: Although the data is secure, the blockchain allows visibility of transactions for all users of the network, ensuring a high degree of transparency.

- Immutability: Once a transaction is recorded in the blockchain, it cannot be deleted or altered, thus providing a permanent and verifiable record of transactions.
- Consensus: transactions must be validated by network nodes through processes such as "proof of work" or "proof of stake", ensuring majority agreement on the validity of transactions.

Blockchain has various applications beyond cryptocurrencies, including supply chain management, electronic voting, digital identity, smart contracts and more, providing solutions for recording and sharing data in a secure and transparent manner.

At the same time, the blockchain is studied and implemented in various ways, considering its qualities and capacities for data processing and processing, but, most importantly, the capacity of its immutability and the security of each individual block.

Field	Specific uses
Communications (C4ISR)	Encryption of communications Credential management
Command and Control (C2)	Management of orders of battle Digital verification of battle orders
Military intelligence	Confidential payments Management of information and sources, their encryption and storage
Military logistics	Supply chain management Inventory management 3D printing Fleet management (land, sea, air, rail, space) Management of critical infrastructures
Instruction	Management of career/personal files
Terrorism and counter-terrorism	Tracking, locating and alerting

FIG. 4. Domains and modes of use [5]

In today's context, where the security and efficiency of military logistics are essential, blockchain technology offers innovative solutions to meet these challenges. Through its decentralized and immutable nature, blockchain can transform the way information and resources are managed in the military. The use of blockchain in military logistics brings an increased level of security, reducing the risks associated with cyber-attacks and data manipulation. Every transaction or movement of resources recorded on a blockchain is verifiable and transparent, thus facilitating better control over supply chains.

Furthermore, blockchain technology can improve efficiency by automating processes through smart contracts. These self-executing contracts can trigger automated resource deliveries or payments based on meeting pre-defined conditions, reducing administrative time and effort. Additionally, blockchain's immutability feature ensures data integrity, a crucial aspect in situations where the accuracy of information can have major strategic implications.

Another important advantage is the improved traceability of resources. In a military environment, where every component, from equipment to supplies, must be precisely tracked, blockchain provides an efficient method of maintaining a detailed record of movements and inventories. This not only increases accountability, but also optimizes inventory management.

At the same time, we can use this technology in:

- **Supply Chain Management for Sensitive Equipment:** Blockchain can be used to ensure the integrity of the supply chain of sensitive and critical equipment, such as weaponry or communications technology. By using blockchain, every stage of the supply process - from production to delivery - can be recorded in a way that does not allow data to be tampered with.

This not only ensures full traceability of the equipment, but also reduces the risk of interception or counterfeiting [3].

- **Securing Operational Communications and Data:** Operational communications and data are vital to the success of military missions. Blockchain can be used to create encrypted communication networks where messages are securely recorded and can only be accessed by authorized entities. This system prevents unauthorized interception and ensures that information remains confidential and protected from unauthorized access.
- **Improving Humanitarian Logistics in Conflict Zones:** Blockchain can be used to coordinate and track humanitarian aid in conflict zones, ensuring that resources reach their destination and are distributed equitably. By using a decentralized and transparent system, the risk of corruption or embezzlement of aid can be reduced. Blockchain can also facilitate collaboration between various governmental and non-governmental organizations in streamlining humanitarian efforts.
- **Improving decision-making processes based on blockchain, AI and deep learning:** The implementation of blockchain, artificial intelligence (AI) and deep learning in decision-making processes is a significant step towards improving efficiency and accuracy within organizations. Blockchain provides a transparent and immutable environment for recording and verifying data, thereby increasing the reliability of information used in decision-making. Artificial intelligence and deep learning enable fast and complex analysis of large volumes of data, making it easier to identify trends and patterns that might otherwise go unnoticed. These technologies also provide the ability to anticipate outcomes and optimize decisions in real time, thus contributing to better adaptability and reactivity in dynamic and ever-changing situations specific to military actions. Using these advanced technologies in decision-making can lead to greater accuracy, efficiency, and ultimately improved performance [6].
- **Use of AI in decision support and piloting of unmanned aircraft (UAV):** The implementation of artificial intelligence (AI) in decision support and piloting of unmanned aircraft is a revolutionary innovation in aerospace technology. AI helps to improve the accuracy and speed of the decision-making process by analyzing a large volume of data and simulating various scenarios in real time. In the piloting of unmanned aerial vehicles, AI provides advanced navigation capabilities and autonomous response to variable environmental conditions, thereby enhancing the effectiveness and safety of missions. These technological advances open new horizons for military and civilian applications, redefining paradigms in aviation and aerospace operations [2].

These examples highlight the versatility and added value of blockchain technology in various aspects of military logistics, from data security to operational efficiency and humanitarian coordination. The innovative use of blockchain in these areas represents an important step towards modernizing and securing military operations.

4. VULNERABILITIES VS OPPORTUNITIES

In the context of the implementation of emerging technologies in military logistics, it is essential to carefully analyze the risks and vulnerabilities inherent in this process. Although the adoption of advanced technologies such as artificial intelligence, blockchain and autonomous systems promise significant improvements in efficiency and security, they also bring new challenges and potential risks.

One of the major risks is vulnerability to cyber-attacks. As technology becomes more complex, so does the risk of exposure to security breaches, malware and other forms of cyber-attacks.

These attacks can compromise the integrity of the military supply chain and have serious consequences, from the loss of sensitive information to the disruption of critical logistics activities [7].

Another vulnerability is over-reliance on automated systems and technology. While automation can increase efficiency, it can also reduce adaptability and the human ability to respond quickly to unexpected situations or system errors. This reliance can lead to a loss of critical knowledge and skills among military personnel, making the organization vulnerable to a technological failure.

Also, the implementation of emerging technologies requires significant investments, both financial and in terms of time and human resources for training and development. There is a risk that technologies will quickly become obsolete due to rapid technological progress, which could lead to inefficient spending or the need for frequent updates, putting additional pressure on state budgets.

Ethical and legal issues are also a major concern, particularly with regard to the use of artificial intelligence and autonomous systems. There are ethical dilemmas related to the delegation of critical decisions to automated systems, as well as the implications of these decisions for international law and the rules of conflict.

In conclusion, while emerging technologies offer significant opportunities for improving military logistics, they also bring with them a complex set of risks and vulnerabilities. It is crucial that these risks are properly assessed and managed to ensure that the advantages of the technology are not overshadowed by its potential negative consequences. This requires a balanced and prudent approach that includes robust cyber security strategies, business continuity plans and clear ethics policies.

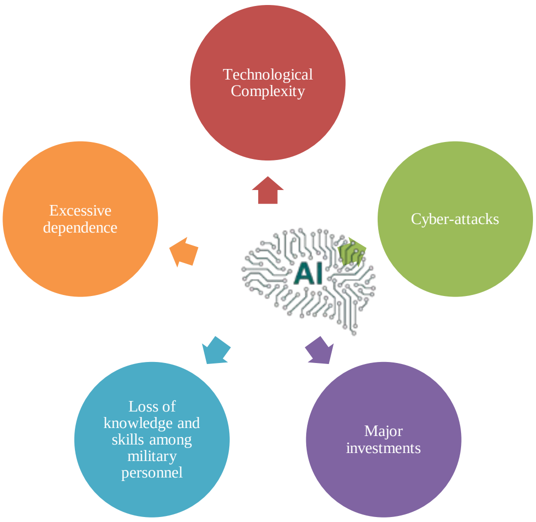

FIG. 5. Major risks in the implementation of emerging technologies

CONCLUSIONS

The research explored the impact of emerging technologies on supply chain management within the military organization, highlighting how technological innovations are redefining the efficiency, security and agility of logistics operations. The bibliometric analysis revealed that the integration of technologies such as blockchain and artificial intelligence leads not only to the optimization of processes, but also to an increased security of data and resources, but also to an effervescence in research in these fields, not far from Sci-Fi.

These emerging technologies offer innovative solutions to traditional challenges such as the risk of human error, cyber vulnerabilities and operational inefficiencies.

By implementing these technologies, military organizations are able to achieve better coordination and monitoring of supply chains, thus ensuring a quick and efficient response in critical situations. At the same time, this technological progress promotes increased transparency and greater accountability, essential elements in the context of military operations. However, the paper also identified challenges associated with the adoption of these technologies, such as the need to develop technical skills and robust security mechanisms to prevent risks associated with complex digital systems.

Emerging technologies have a significant impact on supply chain management in the military organization, offering extensive possibilities for improving efficiency and security. This evolution requires a strategic and adaptive approach, as well as a continuous assessment of risks and opportunities. It is imperative that military organizations stay abreast of technological innovations and proactively integrate them to improve their ability to effectively respond to the dynamic challenges of the modern military environment.

In conclusion, the implementation of blockchain technology in military logistics has the potential to revolutionize this field, bringing more security, efficiency and transparency. As this technology continues to evolve, it is expected that its applications in the military context will become increasingly sophisticated and widespread.

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