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# ARTIFICIAL INTELLIGENCE AS A KEY COMPETENCE OF THE FUTURE EMPLOYEE – HOW AI IS CHANGING LABOR MARKET REQUIREMENTS

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## **Abstract:**

Artificial Intelligence (AI) is a groundbreaking technology significantly influencing the labor market by redefining required competencies in various professions. AI offers opportunities to enhance efficiency and innovation but also raises concerns about job losses, particularly in sectors vulnerable to automation, such as sales and administration. This paper examines the role of AI as a key competence of future employees, analyzing its impact on the development of professional skills, the emergence of new occupations, and social inequalities. It also highlights the importance of integrating technical and soft skills and the need for responsible AI implementation to mitigate potential inequalities.

## **Keywords:**

*artificial intelligence; labor market; automation; professional competencies; social inequalities*

## **Introduction**

Artificial Intelligence (AI) has become a cornerstone of the Fourth Industrial Revolution, fundamentally transforming economies and labor markets worldwide. Its rapid development and applications have revolutionized business processes, bringing increased efficiency and innovation across various sectors. At the same time, these advancements have raised widespread concerns among workers, particularly regarding job security and the ability to adapt to new technological demands.

This paper explores the dual role of AI in shaping the future of work. On one hand, AI acts as a driver of innovation, creating new professions and increasing productivity. On the other hand, it presents challenges, such as deepening social and professional inequalities, particularly among groups with limited access to technology or lower levels of technological education.

The aim of this study is to discuss the impact of AI on the evolution of professional competencies, encompassing both technical and soft skills, and to present strategies for mitigating inequalities through responsible AI implementation, education, and professional training. Analyzing these aspects provides a better understanding of AI's transformative influence on the labor market and its implications for society.

## **Key importance of competencies**

In today's knowledge-based economy, we can observe the growing importance of and increasing investment by companies in developing intellectual capital. Intellectual capital, comprising skills, competencies, know-how, and the collective knowledge of employees, is undoubtedly one of the most critical factors in securing a company's competitive advantage. In the current dynamically changing economic environment, the ability of organizations to adapt to shifting conditions (including technological advancements) and their flexibility in acquiring and developing new employee skills and competencies play a crucial role.

Discussions about the importance of specific employee competencies should begin with clarifying the concept of competencies itself, which has been the subject of much debate and analysis. The literature does not provide a single definitive definition of "competency." For the purposes of this publication, T. Listwan's definition is adopted: "Competencies – the scope of tasks, improvements, and responsibilities assigned to an employee in connection with the position they hold within the organizational hierarchy, as well as the work they perform in a specific functional area of the organization or temporary functions they fulfill. Organizations equip employees with these competencies" [1]. The concept of competence is also related to the term "competency," defined by Armstrong as follows: "Competent people at work are those who meet expectations for achieving specific results. They can use their knowledge, skills, and personal characteristics to achieve the goals and standards assigned to their roles" [2].

It is noteworthy that in the context of the Fourth Industrial Revolution (associated with automation, data-driven work, and artificial intelligence [3]), AI significantly influences the nature of required skills, transforming both technical and soft competency profiles in the workplace. AI primarily demands that employees have the ability to understand and collaborate with modern technologies, even if their daily duties do not directly involve creating or programming such solutions. Competencies related to data analysis, machine learning, and AI interface design are increasingly sought after, not only in the IT sector (as was previously the case) but also in various other industries, such as finance, healthcare, and manufacturing.

## **Artificial Intelligence (AI) – definition, applications, and impact on employee competencies**

The European Commission defines Artificial Intelligence (AI) as: "Artificial intelligence (AI) refers to systems that display intelligent behavior by analyzing their environment and taking actions – with some degree of autonomy – to achieve specific goals" [4]. AI is a technology that significantly enhances numerous organizational processes. Despite the risks it entails, using artificial intelligence in basic, straightforward tasks, as well as in more advanced ones (e.g., requiring larger amounts of processed data), has become a noticeable cause of increased employee efficiency, leading to better business outcomes. The revolutionary nature, popularity, and accessibility of AI mean it is now used across almost every industry and area worldwide and, importantly, in many roles within organizations. Many modern enterprises expect job candidates to have a basic knowledge of AI tools or equip employees with these technologies. It could be argued that in the near future, proficiency in AI tools will be as essential as computer literacy. Reports (SAS, 2018) indicate that 72% of organizations

worldwide use artificial intelligence in at least one area of their business operations, and notably, 51% of companies implementing AI projects achieve success [5]. However, to achieve this success and effectively leverage AI's potential, it is essential to recruit employees who already possess the necessary technical skills for working with modern technologies.

It is noteworthy that AI's impact on employee competencies is not limited to technical requirements. The introduction of automation and AI algorithms into routine tasks means employees must develop skills that are difficult for machines to replicate, such as creativity, empathy, critical thinking, and complex problem-solving. These soft skills are becoming crucial for roles that mediate between technology and humans and for creating innovative solutions to meet market demands. The future of work will require a combination of technical and soft skills, along with continuous adaptability to a changing environment, posing one of the greatest challenges for the modern labor market.

## **Changes in labor market structure and the emergence of new professions**

Artificial intelligence and related solutions can be significant assets for many organizations. Today, there are numerous companies specializing in delivering personalized AI-driven solutions to support other businesses in their operations. Among these are organizations that assist in digital transformation, tailoring AI tools to client needs. Examples of such enterprises include:

- **OpenAI** – An American research lab specializing in artificial intelligence, providing AI models such as ChatGPT [6].
- **Microsoft (Azure AI)** – Offers a cloud-based platform enabling the development and integration of AI solutions across various industries [7].
- **Deloitte** – One of the world's leading consulting firms, actively supporting organizations in AI-related transformation by delivering both strategic advice and specific technological solutions [8].

The development of artificial intelligence naturally leads to changes in the labor market, including the creation of new professions that address the needs associated with designing, implementing, and managing AI-based solutions. AI not only automates processes but also creates opportunities for specialized roles that enable the effective utilization of its potential within organizations. Examples of newly created professions related to artificial intelligence include:

- **Polish AI Trainer** at Upwork – A role focused on training and improving artificial intelligence models, particularly in natural language processing (NLP) for the Polish language. This position is crucial for developing AI systems that require an understanding of specific linguistic, cultural, and contextual nuances [9].
- **AI Development Specialist (LLM)** at Orange Polska – A technical role centered on designing, implementing, and enhancing solutions using large language models (LLM). This position combines advanced technological knowledge with the ability to deploy modern AI solutions in business [10].
- **AI Policy Counsel** at OpenAI – A key position shaping public policies related to artificial intelligence and ensuring the organization's actions comply with legal regulations and ethical standards. This role combines legal expertise with a deep understanding of AI technologies and their societal, economic, and regulatory impacts [11].

The emergence of these professions highlights the need to develop new educational pathways and training programs tailored to current labor market requirements. Organizations and educational institutions should collaborate with companies specializing in AI solutions to ensure future employees have access to the knowledge and tools necessary to work in AI-driven environments. The introduction of AI is not only evolving the labor market but also opening new career opportunities that will be pivotal in the coming decades.

However, the technological revolution of Industry 4.0 may also lead to job reductions in professions most vulnerable to automation, raising concerns about job security. For instance, according to the Polish Economic Institute, among the 20 professional groups most affected by artificial intelligence, specialist roles dominate, such as financiers, lawyers, certain government officials, administrative specialists, and programmers.

Conversely, professions least susceptible to AI impact include manual laborers performing simple tasks in various sectors, cleaners, and machine operators [12]. The integration of AI into the labor market automates many processes, particularly in sectors like sales, production, and administration. As a result, some job roles are replaced by technology, while new competency requirements emerge for employees. Tab. 1 illustrates some of these changes.

Tab. 1. Impact of artificial intelligence on the labor market – sectors, employment, and required competencies

Sector	Impact of AI on Employment	New Required Competencies
Sales and customer service	Automation of routine tasks, e.g., self-service checkouts, chatbots	AI system operation, creativity in customer service
Production	Replacement of line workers with industrial robots	Programming and supervising robots, production process management
Finance and accounting	Automation of financial analysis and reporting	Understanding AI algorithms, data analysis, result interpretation
Administration	Automation of documentation and office processes	Operation of RPA systems, organizing work with AI technology
Healthcare	Support in diagnostics, medical analysis, patient management	Working with decision-support systems, understanding AI in medicine
IT and Technology	Development of new AI-based systems	Technical skills: machine learning, programming, data analysis

Source: own work

## **AI and inequalities in the labor market**

The introduction of artificial intelligence has caused significant concern and apprehension among the general public, particularly among workers. These concerns center on job security and the potential for AI to replace human roles. In my assessment, AI could be a substantial factor exacerbating social inequalities, given its revolutionary and transformative nature and its enormous potential to reshape existing labor structures.

Automation can deepen disparities in employment opportunities across various social groups. For example, older generations of workers are often more vulnerable to the adverse effects of AI due to their limited experience with modern technologies and greater difficulty in retraining. Conversely, younger generations are better equipped to face these changes due to digital education and greater professional flexibility. These groups differ in their level of technological education and their ability to adapt to modern technologies.

Social groups with limited access to technology, such as individuals in smaller towns, less technologically advanced countries, or those in difficult financial circumstances, may struggle to adapt to labor market changes and benefit from AI. These groups might have less exposure to such tools and fewer opportunities for education in this field.

Moreover, analyzing demographic data reveals that women are more susceptible to the impact of AI than men. This is due to their significant representation in roles within sectors such as sales, which are among the most vulnerable to automation (e.g., self-service checkouts or chatbots) [12].

AI, therefore, has the potential to replace certain types of jobs while simultaneously creating new professions and sectors requiring skills tailored to new technologies, such as data analysts or AI ethics specialists. At present, we cannot speak of full automation of many professions – AI and machine learning primarily excel in routine tasks but still require supervision, maintenance, and continuous improvement as technologies.

At the same time, artificial intelligence also has the potential to reduce inequalities, for instance, by enabling remote work on AI projects and, consequently, providing access to the global labor market for employees. However, responsible implementation of AI and investment in training and reskilling programs are critical to enabling all social groups to benefit from the advantages of this technology.

## **Conclusion**

The integration of artificial intelligence into the labor market represents both an opportunity and a challenge. AI has the potential to enhance processes, create new career opportunities, and boost productivity. However, it also carries risks, such as job displacement and the exacerbation of existing social inequalities. To address these challenges, a comprehensive approach is required, encompassing investments in education, the development of adaptability skills, and the responsible implementation of AI technologies.

The future labor market will demand hybrid competencies that combine technological proficiency with creativity, critical thinking, and empathy – qualities that remain uniquely human. Collaboration among policymakers, educators, and organizations is essential to prepare workers for these changes, ensure a fair distribution of the benefits of AI, and minimize risks associated with its

implementation. By adopting these measures, society can harness the transformative potential of artificial intelligence while mitigating its downsides, ensuring sustainable development and equity in the evolving labor landscape.

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## POPULARITY OF ALTERNATIVE TREATMENT METHODS AMONG THE “AMAZONS” FROM THE PODKARPACIE REGION

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### Abstract:

The number of women with breast cancer is constantly growing. Fear and emotional burden do not allow for a critical assessment of treatment methods. The aim of the study was to assess the need for education on alternative treatment methods among women with breast cancer in the Podkarpacie region. We hypothesize that most of them will use them without consulting a doctor. An anonymous survey was conducted among 32 women from the "Rzeszowski Klub Amazonka" Association. 56% of respondents declared having knowledge on alternative treatment methods, but every third of them claimed that these methods do not work and most of them had no opinion. Respondents most often gained knowledge from Internet or family/friends. The most popular were acupuncture, homeopathy and phytotherapy, while the latter two were used by 18.8% of respondents as a supplement to the conventional method after consulting a doctor. Education on alternative methods should include cancer patients and also medical personnel.

### Keywords:

*alternative medicine; alternative therapies; oncology; cancer patients; treatment choice*

### Introduction

According to the National Cancer Registry, the number of people suffering from malignant tumors in Poland in 2019 was over 170 thousand, of which 85 559 cases occurred in men and 85 659 in women. Among these people, 100 thousand died, which is about 25% of deaths in the country. These are patients of different ages and from different social groups. Among women, the most common cancer is breast cancer, with 19 620 cases in 2019 [1]. Currently, over 1.17 million people in Poland live with cancer. Due to the awareness of the risk, patients diagnosed with cancer may approach the choice of treatment methods emotionally, demonstrating a lack of critical assessment. Some patients may refuse conventional therapy [2, 3]. Alternative medicine is defined as "a set of therapeutic methods derived from cultural and social traditions, beliefs and experiences, not supported by the achievements of scientific medicine, and used to maintain health, prevent and

diagnose diseases and treat them" [4]. There is a lot of easily accessible information on unconventional treatment in social media, which is often referred to as innovative and effectively advertised [3]. Due to their wide reach, easy access to a large number of users and the possibility of interacting with other people with similar experiences, social media have become an important tool in popularizing and promoting these methods. On internet forums or virtual support groups for people with cancer, recognized methods of treatment are questioned. The most common arguments are the side effects of conventional methods such as radiotherapy or chemotherapy and the accusation of the business approach of doctors and pharmaceutical companies [5-7]. Alternative methods (AM) such as bioresonance, live blood drop, homeopathy, bioenergy therapy, acupuncture, phytotherapy, blood ozonation or large doses of vitamin C are usually promoted by people without medical education, and the information they present has limited support in reliable literature [2]. Alternative methods of treatment expose patients to deterioration of their health, prolonged convalescence and even death.

The aim of this study was to assess the level of knowledge and beliefs of Amazons from the Podkarpacie region about alternative methods of treatment. Additionally, the study was intended to show the frequency and types of AM used and to highlight the need to educate both patients and physicians on this subject.

## **Materials and Methods**

### **Research tools – questionnaire**

The anonymous survey consisted of 20 closed and open-ended questions. They concerned age, place of residence, education, health situation related to cancer and methods of treatment. Additionally, the questionnaire included questions related to knowledge and beliefs regarding alternative methods of treatment such as bioresonance, live blood drop, homeopathy, bioenergy therapy, acupuncture, phytotherapy, large doses of vitamin C or blood ozonation.

All participants gave informed consent to participate in the study and were informed that they could withdraw from the study at any time without any consequences.

### **Characteristics of the study group**

An anonymous survey was conducted on 32 women from the "Rzeszowski Klub Amazonka" Association. Most of the women lived in cities which may be related to the association's headquarters. The women most often had higher education or secondary education. More than half of the women were in remission, the rest of the women were undergoing treatment. All women undergoing treatment used hormonal medications, 18.2% steroids and 36.4% chemotherapy. The women were aged 45 to 82 years and their average age was  $67.5 \pm 9.23$  years. They had been suffering from cancer for an average of  $14.19 \pm 10.27$  years, the shortest 2 and the longest 39 years (Tab. 1).

Tab. 1. Characteristics of the study group

Age	67.5 ± 9.23 years (45 – 82 years)		
		N	[%]
Place of living	City	26	81.3%
	Village	6	18.7%
Education level	Primary	2	6.3%
	Vovational	3	9.4%
	Secondary	13	40.6%
	Higher	14	43.8%
Duration of the disease	14.19 ± 10.27 years (2 – 39 years)		
		N	[%]
Active disease	Active	11	34.4%
	Remission	21	65.6%
Current treatment *	Hormonal treatment	11	100.0%
	Steroid treatment	2	18.2%
	Chemotherapy	4	36.4%

N - number; % - percentage; \* applies to 11 women

Source: own calculations

## Results

56.3% of the respondents declared that they had knowledge about unconventional methods of treating or diagnosing cancer. Half of the respondents had no opinion on the effectiveness of the methods mentioned, the rest of the group mostly believed that they were ineffective rather than effective. The respondents most often acquired knowledge about unconventional methods of treating or diagnosing cancer from family, friends or from the internet (44.4% of the respondents each). The most familiar alternative treatment methods to the respondents were homeopathy, acupuncture and phytotherapy. However, the respondents more often considered these methods ineffective than effective. However, the majority had no opinion on this subject (Tab. 2).

Tab. 2. Knowledge of unconventional methods of treating or diagnosing cancer

Question	Answer	N	[%]
Knowledge about the existence of alternative methods of treating and diagnosing cancer	Yes	18	56.3%
	No	14	43.8%
Recognizing unconventional methods as effective and scientifically proven	Yes	4	12.5%
	No	12	37.5%
	No opinion	16	50.0%
Sources of knowledge on this topic *	Family/friends	8	44.4%
	Internet	8	44.4%
	Press	3	16.7%
	Doctor	2	11.1%
	Other medical profession	2	11.1%
	Medical literature	1	5.6%
Known types of alternative methods *	Bioresonance	4	22.2%
	Living drop of blood	6	33.3%
	Homeopathy	7	38.9%
	Bioenergy therapy	4	22.2%
	Acupuncture	7	38.9%
	Phytotherapy	7	38.9%
	Vitamin C/blood ozonation	1	5.6%
The effectiveness of the mentioned methods *	Yes	1	5.6%
	No	7	38.9%
	No opinion	10	55.6%

N - number; % - percentage; \* 18 people responded

Source: own calculations

Non-conventional methods of cancer treatment were used by 6 women (18.8%). Half of them used phytotherapy and every third used homeopathy. Half of the respondents used these methods regularly and the other half once or several times. However, most of the respondents did not notice any changes as a result of using these methods. For most women using alternative methods of treatment, it was a complementary treatment to conventional therapy, implemented after starting conventional therapy. Most of the respondents consulted the initiation of alternative therapy with their doctor. They usually used this therapy as a complementary form of conventional treatment and stopped using it after completing conventional treatment (Tab. 3).

Tab. 3. The use of unconventional methods of treating or diagnosing cancer

Question	Answer	N	[%]
Use of alternative treatments	Yes	6	18.8%
	No	26	81.3%
Type of methods used *	A living drop of blood	1	16.7%
	Homeopathy	2	33.3%
	Phytotherapy	3	50.0%
The frequency of using these methods *	Regularly	3	50.0%
	Several times	1	16.7%
	Only once	2	33.3%
Assessment of the impact of these methods on health *	Positive effect	1	16.7%
	Negative effect	1	16.7%
	No difference	4	66.7%
The importance of the above methods in therapy *	Main form of treatment	2	33.3%
	Supplement to conventional therapy	4	66.7%
The time of starting therapy with the above methods *	Before starting conventional therapy	0	0.0%
	After starting conventional therapy	4	66.7%
	Only alternative methods were used	2	33.3%
The reason for using the above methods *	No effect of conventional treatment	0	0.0%
	Supplement to treatment	4	66.7%
	Only alternative methods were used	2	33.3%
Seek advice from a doctor or specialist before using the above methods *	Yes	5	83.3%
	No	1	16.7%
Continuing to use alternative methods after completing conventional therapy *	Yes	2	33.3%
	No	4	66.7%

N - number; % - percentage; \* 6 people responded

Source: own calculations

The influence of age, place of residence and duration of the disease ( $p>0.05$ ) on the respondents' declaration of knowledge about the existence of unconventional methods of treatment and diagnosis was not confirmed. However, this knowledge was more common among women with higher education than among those with secondary or lower education. The influence of education on knowledge was statistically significant ( $p=0.024$ ) (Tab. 4, Fig. 1).

Tab. 4. The influence of selected variables on the knowledge of respondents about the existence of unconventional methods of treatment and diagnosis

Independent variables		Having knowledge about AM		Lack of knowledge about AM		p
		N	%	N	%	
Age	<70 years	10	62.5%	6	37.5%	$\chi^2(1)=0.51$ p=0.476
	$\geq 70$ years	8	50.0%	8	50.0%	
Place of living	City	15	57.7%	11	42.3%	$\chi^2(1)=0.11$ p=0.732
	Village	3	50.0%	3	50.0%	
Education level	Secondary and lower	7	38.9%	11	61.1%	<b><math>\chi^2(1)=5.03</math> p=0.024</b>
	Higher	11	78.6%	3	21.4%	
Duration of the disease	$\leq 10$ years	8	57.1%	6	42.9%	$\chi^2(1)=0.01$ p=0.928
	>10 years	10	55.6%	8	44.4%	

N - number; % - percentage;  $\chi^2$  - Pearson chi-square test value; p - test probability index

Source: own calculations

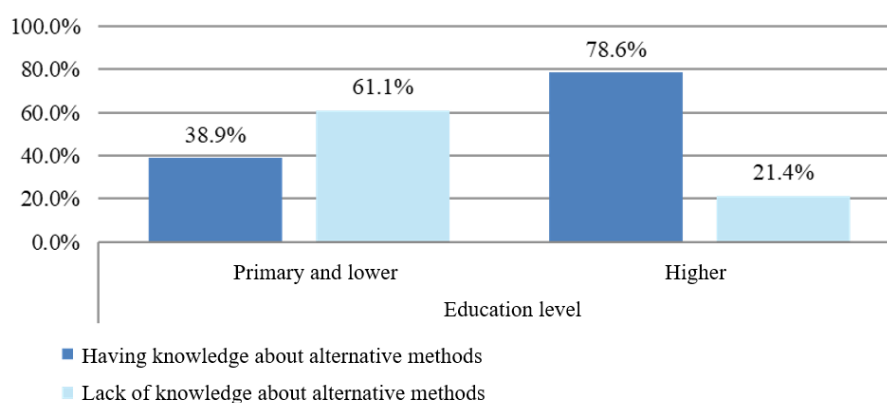


Fig. 1. Knowledge about the existence of unconventional methods of treatment and diagnosis and education

Source: own calculations

The influence of age, place of residence, education and duration of the disease ( $p > 0.05$ ) on the frequency of using unconventional methods of treatment and diagnosis by the respondents was not confirmed (Tab. 5).

Tab. 5. The influence of selected variables on the use of unconventional methods of treatment and diagnosis by the respondents

Independent variables		Use of AM		Not using AM		p
		N	%	N	%	
Age	<70 years	4	25.0%	12	75.0%	$\chi^2(1)=0.82$ p=0.365
	$\geq 70$ years	2	12.5%	14	87.5%	
Place of living	City	6	23.1%	20	76.9%	$\chi^2(1)=1.70$ p=0.191
	Village	0	0.0%	6	100.0%	
Education level	Secondary and lower	3	16.7%	15	83.3%	$\chi^2(1)=0.12$ p=0.732
	Higher	3	21.4%	11	78.6%	
Duration of the disease	$\leq 10$ years	1	7.1%	13	92.9%	$\chi^2(1)=2.20$ p=0.137
	>10 years	5	27.8%	13	72.2%	

N - number; % - percentage;  $\chi^2$  - Pearson chi-square test value; p - test probability index

Source: own calculations

## Discussion

Alternative medicine, also known as unconventional medicine, is gaining popularity. Our own research shows that 56.3% of women with breast cancer from the Podkarpatie region have come across the concept of alternative medicine. In another study, which explored this topic among oncologists from Toruń and Bydgoszcz, as many as 90% declared that they knew the concept [8], while in a study among parents of children with cancer, this knowledge applies to 82% [9]. In this study, the frequency of using alternative methods was 18.8% of respondents. According to other sources obtained in 13 countries, the use of unconventional methods among people with cancer varies greatly and ranges from 7% to 64% [10]. In Norway, this percentage was 50% [3], and in Germany 40% of people with cancer [11]. In women with breast cancer, this frequency reaches up to 90% [11]. In many Asian and African countries, approximately 80% of the overall population believes that traditional medicine, classified as unconventional, is completely safe and uses it as part of primary health care [12]. It happens that the costs associated with AM incurred by patients are twice as high as the costs of drugs prescribed by doctors [7]. In the United States, the number of visits to alternative medicine therapists is increasing by over 200 million per year, and the amounts allocated for this treatment are increasing from 14 to 27 billion dollars per year [9].

The methods best known among the Subcarpathian Amazons are homeopathy, bioresonance and live blood drop testing. Most have no opinion on their effectiveness or do not believe in their positive effects. In a study among nursing students, respondents mentioned methods such as acupuncture, homeopathy and hypnotherapy (100%), ear candling (60%), bioenergy therapy (42%), aromatherapy (40%), bioresonance (20%), phytotherapy and iridology (4% each). Additionally, as many as 32% of respondents suggested the effectiveness of complementary medicine due to the reinforcement of conventional therapy and 25% claim that it is as effective as evidence-based medicine [13]. Every fifth Amazon used one of the alternative methods such as phytotherapy or homeopathy. In the previously mentioned study, nursing students most often used homeopathy (82%) and ear candling (18%) [11-14]. Krizova et al. showed in her research that homeopathy and acupuncture are the methods that enjoy the greatest interest among the group of physicians [14]. On the other hand, only

54% of oncologists claim that alternative methods are ineffective, even though at the same time 92.3% of them claimed that they had not met a patient in their professional practice for whom alternative therapy would be effective [8]. This is disturbing information considering that in this study, patients usually first consulted their intention to use AM with their attending physician. It should be mentioned that women who used alternative medicine did not report any positive effect on health. Also in other studies, respondents consult their intention with a physician. In the study by Woźniak-Holecka et al., it was 59% of women and 66.7% of men [15]. Cancer patients participating in phase I clinical trials rely on their physician for information about their disease 96% of the time, and use the internet for this purpose 89% [16]. Although women with breast cancer look for many ways to combat the disease, half of Amazons know unconventional methods of treatment and most often look for information about them among family, friends and on the Internet. It should be noted that the Internet plays a significant role as a source of knowledge. According to some reports, information contained in the Internet influenced the therapeutic decisions of 13.3% of patients (21% among people under 55 years of age, 24.8% among people with higher education) [2]. According to another study, the most common sources of information for oncological patients are: medical personnel, family, the Internet, medical literature and friends [16]. The results of this study showed no influence of age, place of residence, education and duration of the disease on the use of unconventional methods. Similarly, in relation to knowledge about AM, only women with higher education were more likely to have heard about non-conventional methods of treatment. In the study by Olchowska et al., no correlation was found between factors such as age, gender, education level and readiness to undertake AM among oncological patients [6].

In the study by Krajewska-Kułak et al., nursing students who were disseminated a survey about traditional methods of treatment suggested that there should be a subject in this field at medical schools [13]. This study showed that despite low trust in alternative treatment methods, education about the consequences of their use seems necessary. Increasing knowledge about them should concern both oncology patients and all medical personnel.

The study brings new data on the knowledge and use of alternative methods by people with cancer. However, the limitation of this study is the small number of participants and only one type of cancer was studied. This indicates the need to conduct the study on a larger number of people with different types of cancers, both active and in remission.

## **Conclusions**

Although women with breast cancer are looking for many ways to combat the disease, only half of Amazons know unconventional methods of treatment and they most often look for information about them among family, friends and on the Internet. The best known methods are homeopathy, bioresonance and live blood drop testing. Most have no opinion on their effectiveness or do not believe in their effects. Every fifth respondent used one of the methods such as phytotherapy or homeopathy. Usually, they first consulted this intention with a doctor and people who used them did not find any effect of their use.

The influence of age, place of residence, education and duration of the disease on the frequency of using unconventional methods of treatment and diagnosis by respondents was not confirmed.

A similar lack of influence of the above factors on having knowledge about AM was also noted. Only women with higher education declared this knowledge more often.

Increasing the level of education of both cancer patients and medical personnel seems to be necessary.

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# THE IMPACT OF INFLATION AND GDP PER CAPITA ON THE FOREIGN DIRECT INVESTMENT IN LIBYA

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## **Abstract:**

The primary objective of this paper is to examine the impact of macroeconomic factors, such as the inflation rate and GDP per capita, on foreign direct investment (FDI) flows into Libya. The researcher selected these variables to analyze their short- and long-term correlations by collecting data and information from the United Nations Conference on Trade and Development (UNCTAD) reports for the period 1990–2021. A multiple linear regression model, specifically the Autoregressive Distributed Lag (ARDL) approach, was applied in this study. To assess the skewness, kurtosis, and symmetry of the data, the Augmented Dickey-Fuller (ADF) unit root test was used to check the stationarity of the time series. The existence of cointegration among the variables was analyzed using the Bounds test, while the Jarque-Bera test was employed to verify the normality of the residuals. The empirical findings indicate that there is no causality relationship between the independent variables (inflation and GDP per capita) and FDI flows into Libya in the long run. However, inflation exhibits a positive relationship with FDI in the short run, whereas GDP per capita has no significant impact in the short term. Additionally, it was found that other variables, such as oil and gas exports and the exchange rate of the Libyan local currency against the USD, have a causality relationship with FDI inflows in both the short and long run.

## **Keywords:**

*economic growth; foreign direct investment; GDP per capita; inflation rate; openness trade; oil and gas export*

## **Introduction**

Foreign direct investment (FDI) is widely regarded as a crucial mechanism for fostering economic growth. Over the past few decades, restrictions on capital movement and foreign investment have been closely scrutinized. Many countries, particularly developing nations, have taken significant steps to amend their laws, regulations, and national agreements governing foreign investment. These efforts include opening financial markets and abolishing various restrictive policies and regulations, which serve as key measures to reduce external government oversight and encourage foreign direct investment (FDI) on a global scale.

Despite the global crisis in recent years, caused by the war in Ukraine, high inflation rates (characterized by rising food and energy prices and increasing public debt) foreign direct investment (FDI) flows to emerging market countries continued to grow. In contrast, a decline in FDI was observed in developed nations. For instance, in 2021 and 2022, FDI in developing countries increased by 4 percent, reaching \$916 billion USD, while FDI in advanced economies fell by 12 percent, amounting to \$378 billion USD [1].

A large number of empirical studies have demonstrated the significant contribution of FDI in boosting the economic growth of recipient economies through various methods and models [2]. For instance, [3] and [4] emphasized the potential of FDI as a strategy to stimulate economic growth. Additionally, Ahmed (2012) explored the spillover effects of foreign direct investment on Malaysia's economic growth. Similarly, [5] investigated the cointegration among economic growth, ready-made garment export earnings, and FDI inflows in Bangladesh.

Recently, FDI has been recognized as one of the most significant methods for increasing investments across various sectors, including the production of goods and services as well as infrastructure projects [6, 7]. Moreover, FDI serves as a crucial source for the modern transfer of advanced technology, training of local workers, reducing unemployment rates, boosting exports, and decreasing imports in host countries. However, the majority of foreign investors consider macroeconomic factors before deciding on their investment destinations. These factors include the inflation rate, GDP per capita, the exchange rate of the host country's local currency, and market size. This paper focuses specifically on the impact of inflation levels and GDP per capita.

Approximately 90 percent of foreign direct investment inflows to Libya are concentrated primarily in the energy sector, which is considered the nation's main source of wealth. Oil, in particular, is Libya's principal export commodity and accounts for over 60 percent of the country's total gross domestic product (GDP) growth. While the oil and gas sectors have significantly contributed to Libya's economic growth and helped the nation overcome the poverty it experienced prior to the discovery of oil in 1959, it is crucial for the government to reduce its heavy dependence on oil exports.

To achieve sustainable economic diversification, Libya should encourage FDI in other sectors, such as agriculture, tourism, telecommunications, and manufacturing - following the example of other countries in North Africa and the Middle East. Libya is endowed with a variety of natural resources and holds a strategic geographic location, bridging two major continents, Africa and Europe, which adds to its potential as an attractive destination for diversified investments.

Inflation and GDP per capita are critical macroeconomic factors used to measure a country's economic performance. Numerous scholars have described inflation as an increase in the general price level of goods and services over time across an economy [8]. Inflation is often explained as "too much money chasing too few goods" or defined as the loss of purchasing power of a currency unit, which typically manifests as a general rise in the prices of goods and services [9]. However, [10] argued that inflation can also be understood as the depreciation of money caused by an inflated money supply relative to exchangeable assets.

High inflation levels can lead to various economic issues, while low inflation is often a sign of economic stability. Low inflation can positively affect a country's economy by encouraging foreign direct investment (FDI), as it increases the return on investment. It also stimulates consumer spending and reduces borrowing costs, enabling financial institutions to provide more capital for investment in

housing and construction. In contrast, high inflation is a negative indicator of economic instability. It reduces investment and increases the likelihood of financial disruptions, as businesses struggle to raise prices to match inflation [11]. High inflation often leads to higher interest rates, as central banks typically raise rates to control inflation. This, in turn, increases borrowing costs, reduces consumer spending, and negatively impacts investment, ultimately slowing economic growth [12]. Research has shown that a 10% annual increase in the inflation rate can result in a decline of 0.2–0.3% in the real per capita GDP growth rate and a reduction of 0.4–0.6% in the investment-to-GDP ratio [13].

GDP per capita is defined as the total gross value added by all resident producers in an economy, including any product taxes (less subsidies) not included in the valuation of output, divided by the mid-year population. It can be calculated by dividing GDP at market prices by the country's population [14]. GDP per capita is described as a major indicator of development, influenced by factors such as population size, transparency, and compulsory education [15].

While GDP per capita is not a direct measure of individual welfare, it reflects group well-being and the overall economic performance of societies [16]. A high GDP per capita increases FDI inflows to a host nation due to perceived market potential and higher consumer purchasing power [17]. Conversely, countries with low GDP per capita are less favorable destinations for FDI, except in cases where they offer other attractive advantages, such as lower wages or unique natural resources [18]. Moreover, nations with better human capital and financial infrastructure are better positioned to benefit from FDI inflows, which can further boost economic growth. Thus, a high GDP per capita is generally a positive indicator for attracting FDI, while low GDP per capita may still attract investment under specific circumstances, provided certain factors are available.

Political stability plays a crucial role in determining a country's inflation rate and GDP per capita. For instance, Libya's political instability following the 17th February Revolution in 2011 led to significant fluctuations in both inflation and GDP per capita. In 2011, the inflation rate rose sharply to 15.52%, compared to just 2.80% in 2010. During the period 2016–2017, Libya experienced its highest inflation rates in decades, reaching 25.85% and 25.80%, respectively. Such significant levels of inflation had not been recorded since 1978, when the inflation rate peaked at 29.38% in according to the [19].

The same trend is observed in GDP per capita, which dropped by 32.96%, falling to \$7,784 USD. In contrast, during the period of political and security stability in the country in 2010, GDP per capita was \$11,611. Similarly, in 2020, GDP per capita declined to \$9,872, compared to \$10,973 in 2019.

Therefore, factors influencing the business climate (such as political stability, legal frameworks, and security) are crucial for maintaining low inflation levels and increasing GDP per capita, which in turn helps attract FDI to a country.

## **Literature review**

Hosein (2015) investigates the question: Does foreign direct investment (FDI) contribute to economic growth in developing countries, or is this dependent on the initial conditions of the country? The study uses a sample of developing nations, covering the period from 1970 to 2005. The examination is conducted using the Generalized Method of Moments (GMM) data method.

According to the statistical results, the researcher finds that, in general, FDI has a positive impact on economic growth. However, this impact is still dependent on the conditions of the receiving economy that influence its ability to stimulate economic advancement. The variables tested in the study indicate that there is a positive correlation between domestic investment, human capital, infrastructure development, financial market development, trade openness, and institutional quality on economic growth. However, a negative relationship is observed between the technology gap and economic growth.

Bang Vu (2008) examines the relationship between FDI and endogenous growth in Vietnam by applying time-varying coefficients in an augmented production function. The study allows foreign direct investment to indirectly impact GDP growth through labor productivity. This approach introduces built-in heteroskedasticity, so the feasible generalized least squares (FGLS) estimation method is employed. The empirical results indicate that FDI has a positive impact on labor productivity and economic growth in the country. However, this effect is unevenly distributed across different economic sectors.

Ahmed (2012) aims to investigate the influence of variables such as human capital, absorptive capacity, and physical capital on the level of FDI inflows and GDP productivity in Malaysia. The study uses quarterly data covering the period from 1999 to 2008 and employs the Ordinary Least Squares (OLS) regression technique. The findings show that FDI plays a significant role in driving economic progress through input-driven growth, as indicated by the contribution to total factor productivity (TFP). However, foreign direct investment and the inputs utilized have a negative contribution to TFP. A significant positive relationship is found between human capital, labor force, absorptive capacity, and GDP in Malaysia. In contrast, a negative relationship is observed with respect to physical capital.

Islam (2021) aims to investigate the relationship among the rate of economic growth, ready-made garments (RMG) export earnings, and FDI inflows into Bangladesh. The study uses time-series data covering the period from 1986 to 2018. To determine the cointegration between the variables, the ARDL bounds testing approach was applied, and the Granger Causality test was used to explore the direction of the relationship. The empirical results indicate that both short- and long-run relationships exist between the variables. For instance, ready-made garment exports significantly contribute to increasing the rate of economic growth in both the short and long run. The Granger Causality test confirms a positive causal relationship, showing that earnings from RMG exports lead to economic growth. Additionally, the study finds that FDI has a significant negative effect on economic growth in the short run, but no significant impact in the long run. The results also suggest that ready-made garments attract foreign direct investment to Bangladesh.

Simionescu (2021) aims to determine the role of innovation, FDI, and human capital in supporting competitiveness in EU nations. The study applies the Cobb-Douglas production function, along with other competitiveness factors, using panel data from 28 European countries over the period 2004–2018. According to the hypothesis set forth in the research, FDI, innovation, and human capital contribute to competitiveness growth. The statistical results show that GDP per capita variation is explained by human and physical capital, foreign direct investment, and R&D expenditure. Moreover, human capital plays a crucial role in boosting economic development due to the innovation skills of individuals, which are vital for increasing productivity. Additionally, capital formation positively contributes to economic growth, as supported by the traditional Cobb-Douglas function

framework. According to the study's statistical findings, changes in GDP per capita can be determined by adjustments made in the labor force and capital formation. The researcher also indicates that FDI stock and R&D expenditure play a critical role in economic growth.

Joo, Sana, and Daniel (2022) examine the impact of FDI on various economic characteristics of receiving countries, such as economic stability, human capital, trade openness, and financial development in the BRICS nations (Brazil, Russia, India, China, and South Africa). The data used in the study is based on the World Bank annual reports for the period 1987–2018, and the Least Squares method is employed for analysis. The findings indicate that FDI, on its own, does not have a significant impact on economic growth. However, when the characteristics of the host country are taken into account, a significant positive correlation is observed. For example, when foreign direct investment interacts with trade openness, financial development, and human capital, a positive impact on economic growth in the BRICS nations is noted. Conversely, a negative relationship is observed during periods of economic instability (such as inflation) in these countries.

Hong and Ali (2020) examine the impact of inflation on FDI flows into Malaysia and Iran. The study covers the period from 1986 to 2016, and a range of methods were used to obtain clear statistical results. For example, the Augmented Dickey-Fuller (ADF) test was applied to examine the stationarity of the variables. Cointegration was tested using the Johansen and Juselius test, and the Granger causality test, based on the Vector Error Correction Model (VECM) framework, was used to determine the causal relationships between the variables in both the short and long run. Finally, variance decomposition was used to determine whether the variables are exogenous or endogenous. Based on the empirical results, FDI has an effect on GDP in the short run in Malaysia. In the case of Iran, no causality relationship was found in the short run.

Agarwal and Baron (2018) aim to investigate the bank credit channel through which a sudden increase in inflation causes short-run macroeconomic fluctuations. The study examines the unexpected inflation spike in 1977 in the U.S. and uses variations in state reserve requirements for non-member banks to create distinct inflation risk profiles for these institutions. More exposed banks reduce loans, resulting in a decrease in domestic property values and construction job opportunities. The findings confirm that inflation negatively affects the efficiency of the banking sector.

Robert J. (1995) discusses the correlation between the inflation rate and economic growth in a country. The data collected for this study cover over 100 countries worldwide, with the research period spanning from 1960 to 1990. The author applied a regression equation to assess the impact of inflation on economic growth. The findings indicate that a 10% increase in the inflation rate per year leads to a decline of 0.2–0.3% in the growth rate of real per capita GDP, as well as a reduction in the investment-to-GDP ratio by approximately 0.4–0.6%.

Abdul and Taskeen (2019) investigate the impact of FDI and the real exchange rate on the economic growth rate in Pakistan. The study covers the period from 1980 to 2016, using panel data collected from the World Development Indicators. The ARDL model was applied to examine the causality relationship between the variables. The findings indicate a positive relationship between GDP and the dependent variables. Both the real exchange rate (REF) and FDI contribute to growth acceleration. However, the relationship between GDP, the real exchange rate, and inflation was not significant in the short run.

Ilter (2016) aims to investigate the social and economic factors that influence GDP per capita as a measure of economic growth by collecting data from 40 countries. Regression analysis was applied

to determine the relationship between the independent and dependent variables, GDP per capita. The empirical results indicate that, out of the 11 independent variables used in the study, only compulsory education, population, GDP, and transparency score have an effect on the dependent variable, GDP per capita.

Pakko (1998) indicated that inflation can lead to inefficient resource utilization at a high cost, as consumers often seek to protect the purchasing power of their nominal assets. The article explains these issues, particularly in relation to "shoe-leather costs," a concept in the model where the time spent shopping increases the demand for money. The author states that the shoe-leather costs associated with prolonged inflation, as estimated by this model, are generally consistent with previous research. The study further affirms that changes in inflation rates can involve variables that redefine the welfare impacts. Specifically, the benefits of pursuing disinflation are diminished by the economy's prolonged adjustment period in response to reduced inflation.

Cohen (2023) attempts to provide answers to two questions that were addressed several decades ago, leading to extensive exploration of the limitations of the GDP per capita indicator. However, the researcher argues that these explorations have been unsatisfactory or incomplete. The first question is: What is the significance of GDP per capita to society? The second question is: What does GDP per capita represent conceptually? The paper offers new conclusions that, through these results, could form the basis for a new perspective on the importance of GDP per capita. The article indicates that, while GDP per capita does not represent individual welfare, it refers to the unchangeable well-being of a group. At this point, the author suggests that we must abandon the belief that well-being can be understood solely from an individual perspective. It becomes clear that the orthodox view of GDP as a measure of human well-being requires a shift to an unconventional perspective that considers group well-being.

Khamis, Mohd, and Muhammad (2015) aim to investigate the effect of inflation and GDP per capita on FDI inflows to the United Arab Emirates (UAE). The data used in the study were collected from the World Bank and UNCTAD for the period 1980-2013, covering approximately 33 years. The research utilizes the Autoregressive Distributed Lag (ARDL) model to examine the long-run relationship between the independent and dependent variables in the study. The results reveal that there is no significant impact of inflation on FDI in the country; however, GDP per capita, which is used as a measure of market size, significantly positively impacts foreign direct investment to the UAE.

Selen and Stefano (2006) examine the role of political institutions and market-oriented reforms on foreign direct investment (FDI) within a hybrid model that integrates aspects of both growth-type and gravity techniques. The authors suggest that democracy and economic reform in developing countries have a positive impact on FDI in developed nations. The positive effects of both democracy and economic reform remain significant even after accounting for negotiations regarding EU membership. The authors conclude that the significance of democracy and market-oriented reforms is resilient and extends beyond Europe's borders. The data used in the research primarily come from the OECD's International Direct Investment Database (2006), and the time series for the study cover the period 1992-2004.

## Data and Methodology

To investigate the impact of the independent variables – inflation rate, GDP per capita, oil and gas exports, trade openness, and the exchange rate of the local currency - on the dependent variable, foreign direct investment, we will present the following model np (1):

$$FDI = \beta_0 + \beta_1 INF + \beta_2 PCGDP + \beta_3 OGE + \beta_4 OT + \beta_5 EXR + \varepsilon \quad (1)$$

Where the denotes represent:

FDI	foreign direct investment
INF	inflation rate
PC-GDP	GDP per capita
O&GE	oil and gas export
OT	Openness trade
EXR	The exchange rate of the local currency
$\beta_0$	the intercept term
$\beta_1 - \beta_5$	$\beta_1 - \beta_5$ are the coefficients for each of the independent variables
$\varepsilon$	the error term

### Statistical analysis

The researcher must follow several steps to check the stationarity of the data applied in this study to determine whether the data is stationary at level or after the first difference. If the data is stationary, the Autoregressive Distributed Lag (ARDL) model will be the most appropriate fit.

- Determine the presence of skewness, kurtosis, or symmetry in the data. This is important as it helps assess the central location of indicators that should be considered during estimation.
- Test for stationarity of the time series variables: The Augmented Dickey-Fuller (ADF) test is used for this purpose. This method is an extension of the original Dickey-Fuller test and is helpful in detecting the presence of a unit root in the time series. A unit root in the series (i.e., a root of 1 included in the autoregressive equation) indicates that the series is non-stationary.

### The empirical result

This method utilizes to find if there is any skewness, kurtosis, or symmetry in the data.

Tab. 1. Descriptive statistics

	Mean	Maximum	Minimum	Skewness	Kurtosis	Observations
FDI	8.801	56.580	-12.240	1.426	4.424	32
INF	23.181	265.800	-9.860	3.302	13.618	32
EXR	1.069	4.510	0.280	2.673	13.514	32
O&GE	39.081	66.700	18.500	0.264	1.699	32
PC-GDP	3.285	102.530	-41.390	1.267	6.148	32
OT	71.463	107.620	34.800	0.108	1.628	32

Source: own calculations based on UNCTAD Data for period (1990-2021)

According to Tab. 1, the descriptive statistics of all variables used — FDI, INF, EXR, O&GE, PC-GDP, and OT — are presented with a total of 32 observations. The values indicate that there are negative values recorded in the minimum, with a significant gap between the minimum and maximum values for three variables: FDI, INF, and PC-GDP.

**FDI:** The mean of FDI is 8.801, which is closer to the minimum value. The Pearson coefficient is positive and close to 0, indicating a weak positive relationship. The skewness coefficient is 1.426, suggesting that the distribution is positively skewed, with the tail on the right. The kurtosis coefficient is 4.424, which is greater than 3, indicating that the distribution is platykurtic (i.e., flatter than a normal distribution).

**INF:** The mean of INF is 23.181, which is also closer to the minimum value. The Pearson coefficient is positive, but farther from 0, implying a stronger positive relationship. The skewness coefficient is 3.302, indicating that the distribution is heavily skewed to the right. The kurtosis value of 13.618, which is greater than 3, further confirms that the distribution is leptokurtic, showing extreme values more than expected in a normal distribution.

**PC-GDP:** The mean of PC-GDP is 3.285, which is near the minimum value. The skewness coefficient of 1.267 indicates a positive skew, with the distribution leaning toward lower values. The kurtosis coefficient is 6.148, which is greater than 3, suggesting that the distribution is leptokurtic as well.

In summary, the descriptive statistics reveal large disparities between the minimum and maximum values for FDI, INF, and PC-GDP. Additionally, the skewness and kurtosis values indicate varying shapes of the distributions, with INF and PC-GDP showing more pronounced deviations from normality. The graphs below illustrate the substantial structural changes in these three variables, particularly those showing negative values.

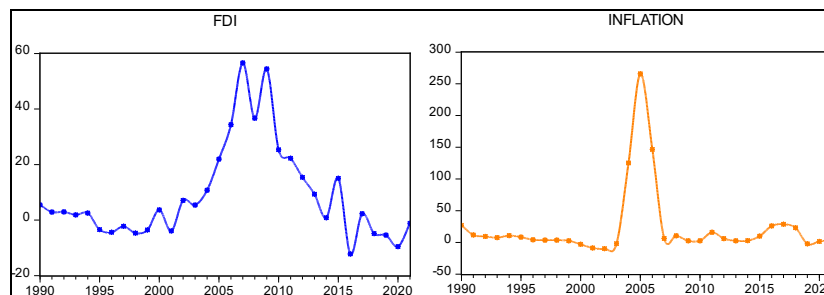


Fig. 1. The variable distribution between FDI and inflation rate  
Source: own calculations based on UNCTAD Data for period (1990-2021)

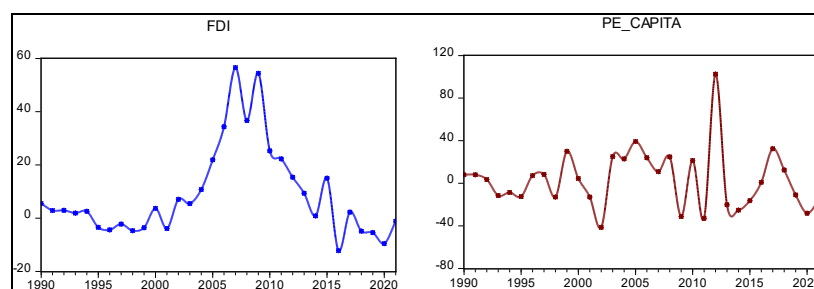


Fig. 2. The variable distribution between FDI and GDP per capita  
Source: own calculations based on UNCTAD Data for period (1990-2021)

According to the graphs presented above (Figs 1 and 2), it is evident that there were noticeable fluctuations in the FDI, INF, and GDP per capita variables during the years 2007, 2008, and 2015. These fluctuations can be attributed to both internal and external political and economic instabilities. For example, FDI saw a significant increase between 2003 and 2010, coinciding with the initiation of various development projects in Libya. These projects spanned several sectors, including telecommunications, transportation infrastructure, agriculture, and industry. However, a sharp decline in FDI occurred after the political instability caused by the civil war following the 2011 Libyan revolution. This political unrest significantly disrupted economic activity, which led to a reduction in foreign investment during and after the conflict.

**Unit root:**

ADF technique apply to check the stationary of the data used based on the null hypothesis ( $H_0 : \beta = 0$ ) explain the time series of the variables if non-stationary and alternative hypothesis ( $H_1 : \beta < 1$ ) indicated that the time series of data is stationary.

Tab. 2. The Result from ADF model Units root

Variables		Constant	constant and trend	Non-constant	Decision
INF	ADF	-4.211030	-4.127559	-3.653878	Accepted at Level
	P-Value	0.0026	0.0148	0.0007	
PC-GDP	ADF	-6.273673	-6.167613	-6.282245	Accepted at Level
	P-Value	0.0000	0.0001	0.0000	
FDI	ADF	-3.024678	-8.538249	-3.083821	Accepted at 1th Difference
	P-Value	0.0443	0.0000	0.0033	
O&GE	ADF	-5.908530	-5.996030	-6.023409	Accepted at 1th Difference
	P-Value	0.0000	0.0002	0.0000	
OT	ADF	-4.783692	-4.700804	-4.858383	Accepted at 1th Difference
	P-Value	0.0006	0.0038	0.0000	
EXR	ADF	-1.383781	-1.224085	-4.380910	Accepted at 1th Difference
	P-Value	0.5768	0.8870	0.0001	

Source: own calculations based on UNCTAD Data for period (1990-2021)

From the results shown in Tab. 2, it is clear that the inflation and GDP per capita variables have p-values lower than the significance levels of 1%, 5%, and 10%, indicating that these time series are stationary at the level. On the other hand, the foreign direct investment (FDI), openness to trade (OT), oil and gas exports (O&GE), and exchange rate (EXR) variables show p-values lower than the 1%, 5%, and 10% significance levels only at the first difference. Therefore, based on the results from the stationarity test, we observe a mixture of variables that are stationary at level and others that are stationary at the first difference. This suggests that the Autoregressive Distributed Lag (ARDL) model

is the most appropriate method to determine the relationship between the independent and dependent variables, as it is capable of handling variables with different orders of integration.

### The cointegration approach Bounds test

This method is typically used to test the level of correlation between variables and to determine if there is a long-run equilibrium relationship between them.

Tab. 3. Bounds Test

Test Statistic	Value	k.
F-statistic	14.53642	5
value Bounds		
Signif	I(0)	I(1)
10%	2.08	3
5%	2.39	3.38
1%	3.06	4.15

Source: own calculations based on UNCTAD Data for period (1990-2021)

Based on the results in Tab. 3, the F-statistic value is 14.5364, which is higher than the critical values for the F-test at the 1%, 5%, and 10% significance levels. Therefore, this indicates the existence of cointegration between the variables.

Tab. 4. The result of Short run test

Short run coefficients				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(INF)	0.002951	0.018434	0.160064	0.8746
D(EXR)	3.958515	1.323207	2.991607	0.0078
CointEq(-1)*	-0.710795	0.061024	-11.64788	0.0000

Source: own calculations based on UNCTAD Data for period (1990-2021)

Tab. 4 illustrates that the error correction coefficient,  $\text{CointEq}(-1) = 0.710795$ , is statistically significant. This means that a long-run equilibrium relationship exists among the variables examined, and any short-term disequilibrium is corrected at a rate of 71.08% per period.

Tab. 5. The result of long Run Test

Long Run Coefficient				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
INF	0.067666	0.039394	1.717662	0.1030
EXR	-12.17740	3.894728	-3.126638	0.0058
O&GE	0.783051	0.174653	4.483474	0.0003
PC-GDP	0.026719	0.058496	0.456758	0.6533
OT	0.060092	0.116998	0.513617	0.6138
C	-20.71483	4.878958	-4.245749	0.0005

Source: own calculations based on UNCTAD Data for period (1990-2021)

From the statistical outcomes in Tab. 5, it can be observed that the independent variables Oil and Gas Exports (O&GE) and Exchange Rate (EXR) are significant at the 1% level. Therefore, the null hypothesis is rejected, and the alternative hypothesis—that there is a long-run relationship between the dependent variable FDI and the independent variables O&GE and EXR is accepted. For example, there is a positive and significant relationship between Foreign Direct Investment (FDI) and Oil and Gas Exports (O&GE). Specifically, a 1% increase in O&GE results in a 0.783051% increase in FDI inflows. Similarly, a 1% decline in the Exchange Rate (EXR) causes FDI to increase by 12.17740%. On the other hand, there is no correlation between Inflation (INF) and GDP per capita (PC-GDP) with FDI flows into Libya, both in the short and long run.

These findings support the work of Khamis et al. (2015), which suggested that inflation does not significantly affect FDI inflows. However, this study contrasts with the findings of Khamis et al. (2015) regarding GDP per capita, which had a significant positive impact on FDI inflows in the UAE.

Moreover, Hong & Ali (2020) investigated the effect of inflation on FDI in Malaysia and Iran and concluded that high inflation negatively affects FDI in the long run. They suggested that supply-side policies should be implemented to reduce inflationary effects and improve productivity. This is relevant in the context of Libya, where inflationary pressures have influenced the economic environment.

The Exchange Rate in Libya was stable for many years, with an average rate of 1 USD = 1.39 LYD. However, the political instability and civil war in recent years, which led to the shutdown of many oil and gas fields, caused a liquidity crisis. In response, the Central Bank of Libya imposed a foreign currency sales tax in 2020, resulting in a dramatic devaluation of the currency (1 USD = 5.15 LYD). [20] argue that a depreciation in the domestic currency can motivate foreign investors to rely more on internal financing, as it becomes cheaper and more manageable for businesses. This suggests that a reduction in the real exchange rate could potentially encourage FDI.

Interestingly, Openness to Trade (OT) had no significant effect on FDI flows into Libya, which contrasts with the findings of [21], who showed that higher levels of trade openness positively affect FDI in both the short and long run. Qamar uz Z argued that lower restrictions on investment encourage multinational companies to invest in a country, fostering economic growth. However, in Libya, FDI has predominantly flowed into the energy sector, particularly oil and gas.

Finally, the findings also align with [22], who suggested that attracting FDI leads to increased oil exports, which in turn fosters economic growth.

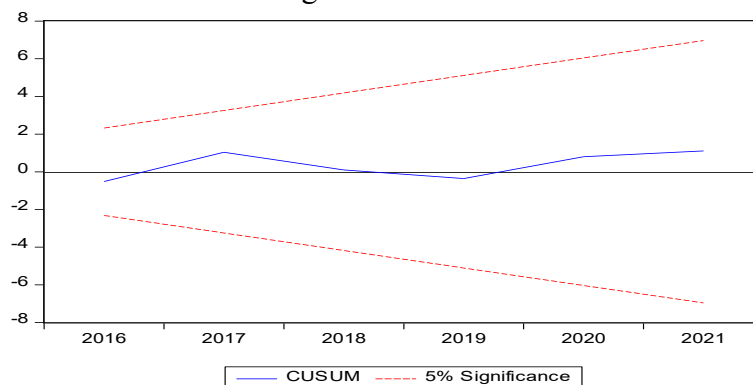


Fig. 3. The stability test

Source: own calculations based on UNCTAD Data for period (1990-2021)

From the above Fig. 3, the chart falls within the critical limits, confirming the structural stability of the model used.

### The Ramsey RESET TEST

This method is used to confirm that all variables have been examined and no variable has been omitted, ensuring that the analysis accounts for all potential factors influencing the results throughout the process.

Tab. 6. Ramsey Test

	Value	df	Probability
<b>F-statistic</b>	2.701259	(3, 15)	0.0828

Source: own calculations based on UNCTAD Data for period (1990-2021)

According to the results obtained in the above Tab. 6, the p-value is higher than 5%. Therefore, it can be concluded that the model is correct and does not include any omitted variables.

### Conclusion and recommendation

The purpose of this research is to investigate the impact of inflation and GDP per capita on foreign direct investment (FDI) flows in Libya. The model applied in this paper is the Autoregressive Distributed Lag (ARDL) model. The process involved examining the data for skewness, kurtosis, and symmetry, which helped determine its central tendency. Additionally, the Augmented Dickey-Fuller (ADF) test was used to check if the time series of the variables were stationary or non-stationary. The results confirmed that the variables are a mix of stationary at level and at the first difference. To investigate the existence of long-run equilibrium between the variables, the Bounds Cointegration Test was applied, and the results showed that the F-statistics exceeded the critical value, confirming cointegration. Furthermore, the Ramsey RESET test was conducted to ensure that all relevant variables were included in the model. The empirical results indicate a causal relationship between oil and gas exports, the exchange rate, and foreign direct investment, both in the short and long term.

Inflation has a positive relationship with foreign direct investment (FDI) in the short run, while GDP per capita has no significant impact on FDI during the same period. However, both inflation and GDP per capita do not affect FDI flows in Libya in the long run. Openness to trade also does not show any impact on FDI flows in Libya in either the short or long term. Over the past few decades, Libya has faced several internal and external challenges that have affected its economic environment. For example, from 1992 to 1999, Libya was under United Nations sanctions, which included financial restrictions and limitations on international trade. During this period, financial losses were estimated at nearly 34 billion USD. The inflation rate reached over 10.35%, largely influenced by the global financial crisis in 2008. Another significant challenge occurred in 2011 during the 17th February Revolution, which negatively impacted both local and foreign companies. Over 90% of foreign companies ceased operations in Libya due to security instability. The inflation rate surged to 15.35% in 2011, up from 2.80% in 2010. However, in recent years, Libya has experienced relative stability, with inflation rates of 1.25% and 2.87% in 2020 and 2021, respectively.

The average GDP per capita during the sanctions period (1992-1999) was 5,200 USD. During the periods of economic and security stability, the average GDP per capita reached approximately 1,158 USD. In conclusion, macroeconomic factors have not significantly influenced FDI flows in Libya. This could be attributed to the fluctuations caused by political and economic instability over the past three decades. Therefore, it is crucial for the government and political parties to intensify their efforts in creating a roadmap to establish long-term economic and security stability. These factors are essential for fostering a business-friendly environment that can attract foreign direct investment to Libya.

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# USE OF LATTICE STRUCTURES FOR VARIOUS COMPONENTS OF SATELLITES

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## **Abstract:**

Every satellite requires a structural component, capable of installing different subsystems and sensors either inside or outside the spacecraft. One of the most important limitations is the budget mass, which directly impacts satellite capabilities. Also, a rising threat from space debris may require introduction of additional shielding to protect most vulnerable components of the satellite. This in turn may limit capabilities of the satellite, as the mass budget would shift more into the inert mass required for structures. In this project our team developed novel 3D printed lattice structures, which are lighter than traditional "solid" counterparts and at the same time can perform additional functions. The novelty is to use small cells as "building bricks" and capability to design structures with additional functions, such as thermal channels or electrical connectors. In result, the mass of the satellite structure can be lowered, which would increase the overall performance of a spacecraft. Project realized under the POIR.01.01.01-00-0581/17 contract with the Polish National Research and Development Center.

## **Keywords:**

*3d printing; lattice structures; satellites*

## **Introduction**

Since the introduction of the "Starlink" mega-constellation, the number of satellites has increased significantly. According to available statistics, in 2010 there were around 1,000 active satellites on various orbits. A decade later, this figure rose to over 3,200. By April 2024, the number of active satellites reached 9,000 [1]. The U.S. Government Accountability Office projects that around 60,000 active satellites could be orbiting the Earth by 2030 [2]. This significant increase in satellites is driven by several factors:

- A rising number of available launch rockets capable of delivering various satellites to specified orbit(s);
- A lowering launch cost per kilogram or per volume;
- Overall progress in subsystems miniaturization, leading to smaller yet still capable satellites;
- A shift from large satellites to constellations or mega-constellations

- An introduction of technologies, such as Commercial Off-The Shelf products, standardized satellite buses/platforms, miniaturized components or advanced (and smaller) propulsion systems significantly lowered costs and streamlined satellite production.

However, it is clear that despite all recent technological achievements a design of a satellite still faces a constraint of relatively high fraction of a mass budget required for the structure of each spacecraft. In general, the higher the structural mass fraction, the lower available mass for other components, such as payload and/or propulsion system. A study from 2023 indicates that the payload mass fraction is typically in the range between 0.0 to 0.4, depending on presence and complexity of the propulsion system [3]. The total structural mass fraction of a satellite can often be as much as 0.5, as presented by several modern satellite producers, when all components, such as connectors, harness, holders and the structure itself is taken into account [4, 5]. The mass fraction of a “dry” structure is typically between 0.1 to 0.2 range.

In addition, due to a rising number of space debris, there may be a rising need to increase shielding of critical or sensitive systems [6]. For example, wire bundles can be damaged as a result of interaction with debris ejecta. Such exposed wiring may be critical to various phases of satellite missions, including disposal, which typically happens years after orbit insertion. Also, satellites may explode due to presence of residual fuel in tanks or improper operations of on-board power systems or batteries. One such recent case is a breakup of the Intelsat 33e satellite in October 2024 [7]. As a result of a breakup, hundreds of space debris were detected.

While it may not be possible to eliminate some parts of satellite structure, it may be possible to introduce higher integration and new technologies, which would result in a lower mass budget. An example of such a technology, which still has not become widespread in the space sector, is additive manufacturing. This work focuses on exploration of lattice structures for structural elements of satellite systems. The novelty is to use small lattice cells as "building bricks" and capability to design structures with additional functions, such as thermal channels or electrical connectors.

This work presents results from a project which was realized by Blue Dot Solutions Sp. z o.o. company under the POIR.01.01.01-00-0581/17 contract with the Polish National Research and Development Center.

## **Methods**

Lattice structures were designed using the ANSYS and Solid Edge software with the following assumptions:

- They should be composed of “building bricks”, which are repeatable and can be fabricated via additive manufacturing, which takes into account possible limitations of available current 3D printing technologies,
- The initial size of each "building brick" would be in order of tens of millimeters, yet they could be changed, depending on the needs of particular structural part of the building a vehicle,
- The complexity of such "building bricks" should be relatively low, thus minimizing possible production defects,
- Selected manufacturing methods: FDM and SLS, due to their widespread popularity and availability of precursor materials and printing services,

- Created lattice structures, in forms of flat plates, would undergo series of tensile tests to understand its mechanical properties,

After tests, a prototype would be fabricated to demonstrate basic functionality of the whole concept of lattice structures. Selected materials for testing were:

- Polylactide (PLA) plastic for fast and inexpensive manufacturing and initial verifications,
- Alumide, which is an inexpensive mixture of polyamide and aluminum, often used for prototypes,
- Aluminum (AlSi10Mg alloy), which is a popular alloy used in the aerospace industry.

## Results

Fig. 1 presents several types of “building bricks” designed during this project. Among them, numerical simulations indicated that cell “1h” exhibits the highest mechanical performance while keeping the general complexity of additive manufacturing low.

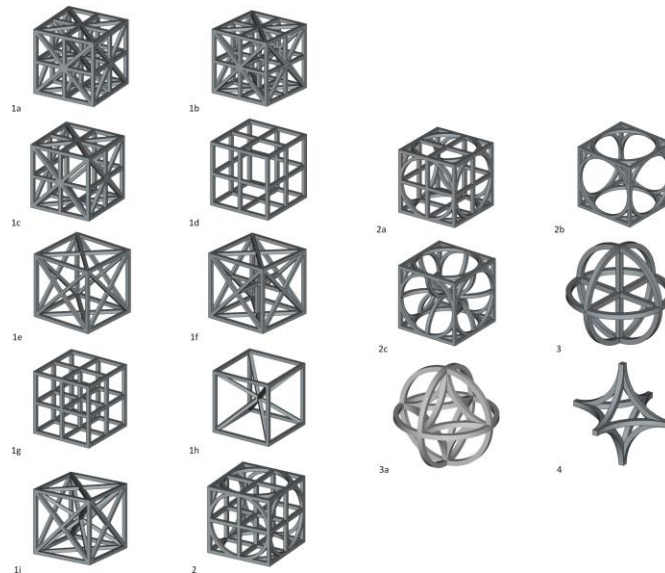


Fig. 1. Examples of cells (“building bricks”) designed for this study

Source: own work

Next, destructive mechanical properties were tested on fabricated plates of lattice structures. An example of a destructive mechanical test is presented in Fig. 2 below. Obtained results were in a range between 2.36 and 25.6 kN at breakup, which corresponds to strength between 250 to 500 MPa for the AlSi10Mg alloy. The lower values were noted in the case of very thin cell structural elements, likely containing defects inside each structure. On the other hand, obtained results from thicker cell structures closely match reference values for AlSi10Mg alloy. These results indicate that there were no defects inside these structures.



Fig. 2. Example of an aluminum lattice structure plate broken after tensile test  
Source: own work

Prototype battery containers fabricated from the selected materials are presented in the Fig. 3. Each container was designed with a top lid attached to the rest of the structure using standard M3 screws. These containers were fabricated from PLA, Alumide, and aluminum alloy. A close inspection revealed no visible external defects, indicating that the designed “building bricks” are suitable for fabrication using modern commercial and industrial 3D printers, as well as post-processing treatment methods.

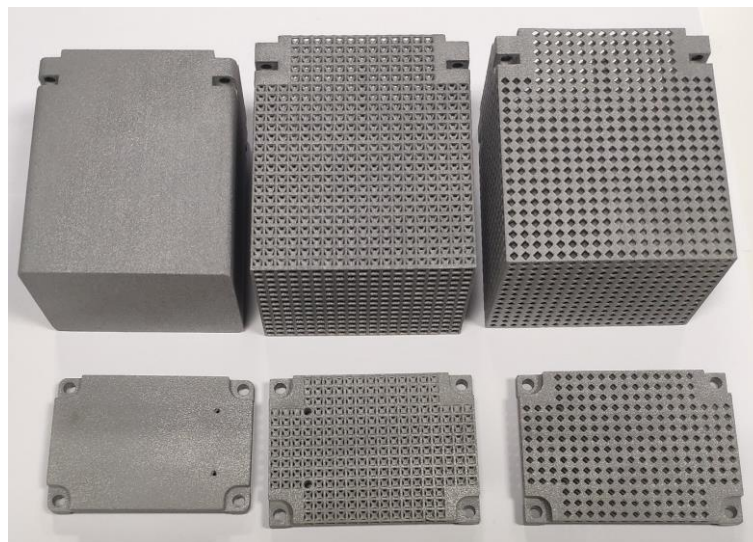


Fig. 3. Examples of battery container prototypes with lids. These prototypes are made of Alumide material  
Source: own work

A prototype battery container fabricated from lattice structures is presented in the Fig. 4. The lid of this prototype battery container is removed to expose the battery pack, battery discharge controller and wiring. In addition, this particular battery pack container is composed of two separately fabricated containers, one of which is inserted into the other one. The objective of placing one container inside

the other one is to demonstrate good fitting of separately fabricated structures. This is an important feature for satellite manufacturing, where high precision of placement of each module or component is required. The Figure below also presents a microcontroller (Arduino Mega device), an electronic load, a breadboard and SD card board. This setup allowed to record a typical battery discharge scenario.

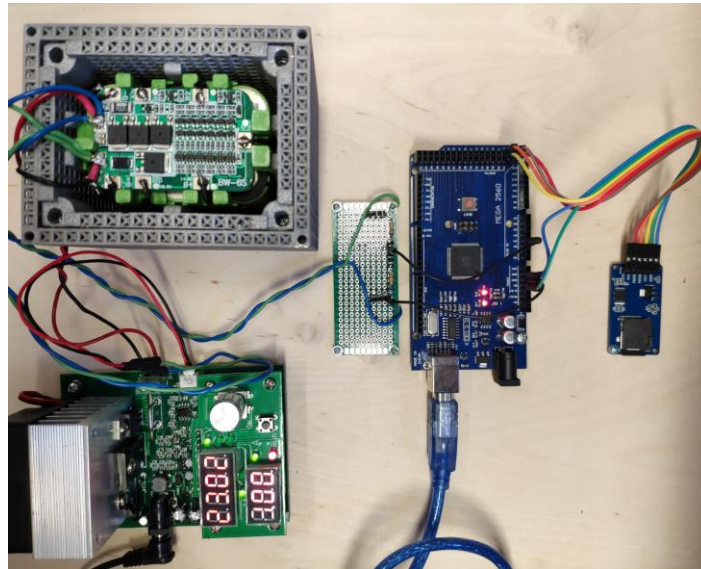


Fig. 4. An experimental set containing a prototype dual-layer battery container with battery pack (top left) with electronic load (bottom left), microcontroller with breadboard (center) and SD card reader (right)

Source: own work

Finally, the mass savings for the lattice structures were measured to be between 33–48% compared to similar solid structures (in the case of flat panels, depending on the type of cell). This value may vary for other geometries. One particular example involved the use of lattice structures in a complex, semi-circular container for a commercial satellite mechanical device [8]. The baseline structure design (without lattice structures) had a mass of 1578 g. The lightweight version, incorporating lattice structures in certain parts of the container, reduced the mass to 1242 g, resulting in a 22% mass savings. In this specific case, there were plans to install as many as six such containers. The use of lattice structures would mean that the total mass savings exceeded 2 kg, greater than the mass of one container.

## Summary

Lattice structures were successfully fabricated from three different materials with the use of FDM and SLS additive manufacturing methods. Several cells were investigated and among them the “1h” variant was found to exhibit the most suitable mechanical properties while keeping the complexity of fabrication low.

Subsequent mechanical tests indicated that, apart from very thin structures, these cells are defect-free and have strength similar to reference values. At the same time, fabricated structures have very good fitting and can be inserted or connected to other structures. These results indicate that it is possible to use these “building bricks” both as main structural elements of satellites and as supporting

structures, where for example mechanical load is smaller. A practical commercial case on a complex structure indicated that mass savings are significant, especially if multiple containers or structures are required in a single satellite.

The above results open up the possibility of a wider application of lattice structures composed of “building bricks” for satellites. Thanks to the capabilities of modern additive manufacturing, it is possible to fabricate lightweight structures capable of performing major roles in satellite manufacturing.

Future work may include testing samples in real space conditions. The European Space Agency (ESA) runs a series of calls for experiments onboard the International Space Station (ISS). Occasionally, calls are also issued for experiments to be placed on special platforms outside the ISS.

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- [8] Author’s comment: due to commercial sensitivity it is not possible to disclose figures containing designs with and without lattice structures.

# A CONCEPT FOR HYBRID GNSS/UWB NAVIGATION SYSTEM FOR AIRCRAFT GROUND HANDLING ASSETS TRACKING

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## **Abstract:**

The tracking of ground handling assets, such as pushbacks, buses, and tractors, is essential in modern logistical systems for efficient asset monitoring. However, challenges arise when assets operate in dual environments: open areas like aircraft servicing zones and indoor spaces. Additionally, some devices require prolonged autonomous operation. This study presents a hybrid positioning system combining GNSS technology with supplementary non-GNSS solutions to address these challenges. Tests conducted at Gdansk Airport evaluated the performance of GNSS units in live operations and integrated a secondary navigation platform based on UWB/BT technology. This platform employs Two-Way Ranging (TWR) and Time Difference of Arrival (TDoA) methods to ensure reliable indoor positioning. The system is designed to seamlessly transition between environments and mitigate GNSS signal loss caused by jamming or other disruptions. Simulation results demonstrate that the hybrid system bridges the indoor-outdoor positioning gap, maintaining precise asset location indoors and serving as a backup during GNSS outages. Furthermore, the UWB system provides a secondary data transmission layer, primarily for timing synchronization but also as an alternative to mobile networks for data transfer. The findings validate the hybrid approach, showing its potential to enhance asset tracking systems in diverse operational scenarios. Project has been realised under the RPPM.01.01.01-22-0099/16 contract with the Pomerania Development Agency Co.

## **Keywords:**

*IoT; GNSS; UWB; ATWR; TDoA*

## **Introduction**

Ground handling operations require many types of specialised assets to properly serve a diverse selection of modern aircraft of broad range of sizes. To properly allocate those assets we have developed a GNSS-based system which proved that even in a challenging environment a precision better than 1 meter is achievable. For most cases this precision is sufficient as a support to typical daily operations. However, this system has been generally limited to the assets which were operational under open sky, with position being determined directly by GNSS.

Ground handling operations at airports rely on a wide range of specialized assets to service modern aircraft of varying sizes. Efficient allocation and tracking of these assets are crucial for smooth operations. To address this need, we developed a GNSS-based system capable of achieving

sub-meter precision, even in challenging environments. While this level of accuracy supports most daily operations, the system is limited to assets operating in open areas where GNSS signals are unobstructed. As a result, equipment used near buildings or inside terminals remains untracked or tracked only intermittently due to reliance on auxiliary navigation sources. Based on the information provided via initial testing phase it was possible to ascertain the amount of time associated with each equipment groups which illustrates Tab. 1.

Tab. 1 summarizes the activity patterns of various asset groups at Gdańsk Lech Wałęsa Airport, a medium-sized airport with a single runway. These data highlight the operational characteristics and challenges associated with tracking equipment, particularly in mixed indoor and outdoor environments.

Tab. 1. Activity of equipment as in asset classes

Asset group	Units	% Use	Season	Propulsion
GPU (Ground Power Unit)	24	70	All year use	Towed only
TBL (Towbarless Tractor)	3	100	All year use	Self propelled
TT (Tank Truck)	2	100	All year use	Self propelled
Belt Loader	12	100	All year use	Self propelled
E-Tractor	25	100	All year use	Self propelled
Car	14	100	All year use	Self propelled
Bus	4	80	All year use	Self propelled
Water Service Unit (WSU)	2	50	All year use	Self propelled
Toilet Service Unit (TSU)	2	50	All year use	Self propelled
Air Start Unit (ASU)	2	10	All year use	Towed only
De-Icing Vehicle	3	100	Winter only	Self propelled
Heater	6	100	Winter only	Towed only
Loading Platform	3	60	All year use	Self propelled
Self-propelled Stairs	3	100	All year use	Self propelled
Towed Stairs	18	100	All year use	Towed only

Source: own calculations under test phase of the project

Untracked or partially tracked assets, such as towed tractors, frequently transition between indoor and outdoor zones, introducing several challenges. For example:

- **Multipath Errors:** Near large structures such as terminals and hangars, GNSS signals may reflect, leading to positioning discrepancies [1].
- **Indoor Operations:** Some equipment operates within confined terminal spaces where GNSS is unreliable or unavailable.
- **Power Constraints:** Prolonged operation of GNSS tracking systems with frequent updates significantly increases power consumption, limiting their use for assets without robust power sources.
- **Infrastructure Requirements:** Alternative solutions, such as RFID or QR codes, offer limited functionality and necessitate costly infrastructure modifications, which are impractical at active airports.

To address the challenges of tracking ground handling assets in complex environments, we propose a hybrid positioning system that integrates GNSS with RTK-enabled technology for outdoor

tracking and a UWB/BT-based platform for indoor operations. UWB (Ultra-Wideband) technology offers high-precision ranging through short-pulse transmissions over wide frequency channels, while Bluetooth provides supplementary communication. This combination ensures seamless transitions between indoor and outdoor environments and maintains reliable tracking even during GNSS disruptions (e.g., jamming). Our study evaluated GNSS and GNSS/RTK technologies under real-world conditions at Gdańsk Airport and assessed UWB-based platforms for confined spaces. By integrating these technologies, we developed a simulation model to project the system's capabilities. A 3D visualization tool was also created to enhance situational awareness and operational efficiency by representing asset locations and movements.

A case study at Gdańsk Lech Wałęsa Airport, a medium-sized airport with a single runway, highlighted limitations of existing tracking systems, particularly for assets that must utilize independent power sources. A significant fraction of equipment remains untracked or partially tracked, especially in:

- **Zones of Active Aircraft Servicing:** Proximity to terminals and hangars often causes multipath GNSS signal errors, leading to positioning discrepancies.
- **Indoor Operations:** Equipment frequently operates in confined spaces, such as terminal interiors, where GNSS signals are unreliable.

Assets like tractors, used for transporting luggage and towing other equipment, present additional challenges due to their frequent transitions across indoor-outdoor boundaries. Continuous GNSS operation for these assets indoors is not a viable location finding solution and the power drain can further complicate long-term tracking. Other existing solutions, such as QR codes, RFID systems, or infrastructure-heavy alternatives, offer limited effectiveness and scalability.

Our proposed hybrid system bridges these gaps by combining GNSS/RTK for precise outdoor tracking with UWB/BT technology for indoor and transitional environments. The UWB platform, built on Decawave's DWM1000 chip, enables precise two-way ranging and integrates Bluetooth communication for additional functionality. This synergy enhances tracking reliability, ensures resilience to GNSS disruptions, and minimizes infrastructure dependence. The system's performance was validated by overlaying test data with real-world operational data from the airport. The resulting spatial insights illustrate its potential to transform asset tracking in environments requiring seamless indoor-outdoor transitions, such as airports, seaports, and logistics hubs. The integration of GNSS/RTK and UWB/BT technologies paves the way for innovative, modular positioning systems adaptable to various operational needs.

In addition, a 3D visualization tool was developed during testing to display asset locations and movements within a dynamic environment, providing a comprehensive and intuitive operational overview. Altogether, this hybrid system represents a robust solution for tracking challenges in modern transportation and logistics settings.

### **GNSS/RTK primaries (active units)**

To provide the operational backbone, the main component consists of a GNSS tracker with RTK capability and with LTE communications to the server. It is possible to operate system components without RTK, but with limited precision. However, the main operational mode is intended to utilize either local, independent RTK base station that supplies required RTCM corrections or external,

independent service such as EUPOS. The basis of data exchange is still LTE-based, as those devices require constant incoming and outgoing data flow. First phase of the Ground Eye project tests, which included several prototypes of the active devices working independently, has proven that even with previous generation of GNSS receivers, supporting only single band and three satellite constellations (GPS, Galileo and GLONASS) it's possible to have a system with decent positional capabilities in-line with general requirements of the ground handling operator.

The spatial precision which in this case was lowered to about 1-2 meter, ultimately can still be useful as each active unit is generally associated with equipment that is either working within the designated service area for the aircraft (slot) or is stored in one of many equipment standby zones, scattered over the airport fields of operations. This means that even without the full positioning highly precise capability, the system may in fact be capable of identifying if the device is within the aircraft zone of operations or is waiting in one of the standby zones. Furthermore, this simplifies position reporting under emergency mode while primary GNSS position reporting is known to be jammed. System can report if the tracked asset is at certain distance to known reference point and with possible cross reference with the general map of the airport it can guess the position of the asset even without the precise knowledge of the position.

The obvious limitation of the system is that it requires constant access to a sufficient power supply, therefore active units can only be installed in vehicles that contain large primary power pack or significant secondary power, where a large battery supports operation while engine and thus alternator is off. Phase one tests shown however that it is possible to mitigate this problem to some degree by utilizing a backup power source on the active devices themselves that support constant operation while main power bus is offline. This is caused by the fact that diesel and electric assets only provide DC line when in operation.

Naturally, this issue can be solved, but use of main power source that vehicles uses in order to operate separate, add-on systems creates additional strain over the vehicle power source which is unfavorable. Since typically assets remain mostly in dormant state and only become active when changing location, the overall charging time that could restore some power within backup power source is very short. This can be mitigated to some degree by increasing the charging current, however this negatively impacts the backup power source operational life span, and can potentially introduce fire hazard, which makes it unsuitable for the airport use. The alternative solution is to connect units directly to the main power source through more sophisticated power converter that could lower the operational voltages from a hi-voltage input to low-voltage output required by active tracking units (for sustained operation and backup power source charging). But the overall power drain in comparison to the typical asset operation is minimal.

Furthermore, the second generation of tracking units would utilize new, dual-frequency receivers that also allow system to work over four available constellations (GPS, Galileo, GLONASS and BEIDOU). This significantly increases the availability of source positioning signals and therefore allows for a better, more robust navigation. New receivers could also integrate dead reckoning technology to provide valid positional input, while satellite source becomes corrupted or unavailable. For testing purposes the uBlox ZED F9P-series receivers have been used as a reference base for dual-frequency units (1.207 GHz - 1.246 GHz and 1.561 GHz - 1.602 GHz) and NEO M8N and M8U for single frequency of 1.575 GHz.

GNSS reception for positioning is the main way of establishing positions of the tracked equipment in the airfield, which our collected data suggest can be very reliable, especially when used with additional RTK reference station set up locally. However this method of positioning has been proven to not be reliable within buildings, which ultimately is a necessity in case of several classes of equipment. Furthermore some sections of the airfield (in example being close to high buildings) can limit the availability of positioning signals due to multipath errors in close vicinity of the terminal or large hangars.



Fig. 1. A composite image containing all tracked data presented on a map of airport, colour represents how often assets have been detected in the area (red – most often)

Source: data collected under testing phase

As presented in Fig. 1 the results are in line with the expected positions the tracked assets take regularly from one of the several standby zones (seen as red fields) towards the aircraft zones of operations and for the most part overlaying the markings associated with designed vehicle allowance sections of the airport itself, which is fully described based on airport mapping subsystem and the positioning capability of the GNSS receivers.

### **UWB/BT supplementary secondaries (passive units)**

In order to close the positioning gap, the newly proposed system architecture introduces ultra-wideband technology (UWB) alongside BLE to fulfil the needs of tracking non-powered assets. As certain elements of the system require positioning to be active without the GNSS satellite signals, an alternative positioning system may be employed specifically to work when GNSS positioning is not available. One of possible solutions is a system that uses reference points that are non-moveable with associated known locations. The moving subject send a radio signal which is intercepted by a set of bases which all are synchronized to common source. Therefore it's possible to calculate the signal travel time for tracked object or person to every device configured to receive this signal and being in range. This is non-surprisingly a typical operation for such system when used solely indoors.

Those devices are optimized for long-duration operations without external human supervision and utilize two possible methods of providing location identification. In the primary mode, which utilizes high-precision ranging, two devices that utilize UWB modules can obtain information about

their relative distance to each other. This is possible because the modules themselves work at extremely high frequency, that allow counting the microsecond delays between when the signal was sent by originating unit and when it actually registered response. Subsequent testing of this approach provided results with a very decent precision typically no less than 25 centimeters. However, this mode of operation (TWR) is somewhat power inefficient, because signal needs to be processed and proper response sent back by the secondary (responder) device that is called from the primary one (initiator). Thus, a secondary mode of operation can be introduced that only utilizes so-called ‘blink’ packets via TDoA method [2]. Those packets are sent periodically and are registered concurrently by several devices acting as relays. Knowing the position of those units, provided by the primary navigation GNSS/RTK system and maintaining synchronization between those units clocks, it is possible to calculate position of the origin of the ‘blink’ signal through time difference of arrival principle. Furthermore, it is also possible to obtain positional information by utilizing conversion between Bluetooth relative signal strength indicator (RSSI) and pseudo ranges when combined with one of several available conversion models [3]. While TDoA method is more demanding when compared to TWR method, mainly due to necessity of maintaining very precise synchronization levels, it can also provide decent level of precision – typically no less than 10 centimeters [4]. For evaluation purposes the DWM1000 units has been selected for testing, which did not include Bluetooth technology.

Combination of GNSS/RTK system typically used for outdoor use with UWB system (originally introduced as a way of navigating indoors), provides some interesting capabilities, that are otherwise impossible to obtain with WiFi or BT technologies. Firstly, such a hybrid system allows for smooth, seamless transition from outdoor to indoor use. This is possible because the UWB system in active units can be used also as a source of positional information if the primary GNSS modules cease to send valid data. Therefore, a vehicle that transitions from outdoor use to indoor operation, which is not uncommon to some classes of ground handling assets, maintains its connection to the system by LTE and sends position seamlessly. Technically this option is no different than standard implementation of the UWB based system, with anchors being installed permanently in designated locations within building in known positions (either relative or absolute).

Furthermore, in situation when GNSS is unavailable due to wide-area jamming, the last recognized position could be provided by devices which were known to be in a stationary state. If at least three such devices are within wireless range of each other and they cover the area of interest and it would be enough for the position to be obtained through UWB back system. This is essentially the basis of the redundant operation mode. Additionally UWB system can provide limited positioning information understood as a distance from certain base of known location which with additional spatial information of the area could be used to ascertain the position of tracked object.

## **Principle of operations**

The main network uses devices incorporating the GNSS receivers that may work in default or RTK mode, in a latter case providing location information in standard ‘rover’ type operation. The precision of such GNSS receivers is typically higher with the dual frequency, multi-constellation operation, at resolution that is within decimetre range with tests providing input which was typically better than 50 centimetres. This result was effectively much higher than values obtained under initial

testing phase with single-frequency variant of the receiver. However, some option to mitigate this problem in case of single-frequency receiver has been tested by utilizing median integration of the gathered positions while devices were stationary. Both receiver types can also provide a synchronized time-pulse output. Therefore, it is theoretically possible for each unit to act as mobile base for a secondary network which is based on UWB technology. This effectively allows additional tracked units – TAGs – to be detected and their positions calculated via TDoA method using their standard ‘blink’ frame, a default method for sending signal identified by local bases running synchronously. A Fig. 2 visualises this concept.

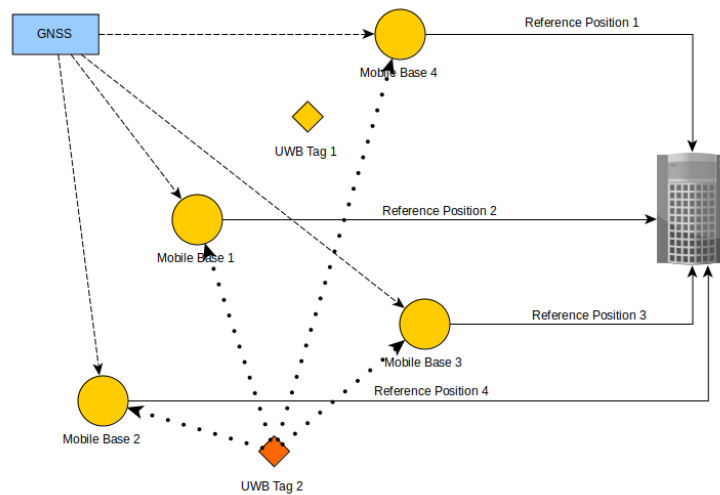


Fig. 2. A schematic of the communication between mobile bases, tags and server; dotted lines represent ‘blink’ signals being sent and received by mobile bases synchronised over common GNSS reference; this mode however requires very precise PPS synchronisation which may be hard to achieve using low-cost receivers  
Source: own work

The typical operation of the UWB subsystem is generally used for positioning of assets travelling in close proximity to buildings or indoor as certain classes of equipment crosses from open sky GNSS positioning into localised indoor system based on UWB technology.

### Typical operation mode for indoor positioning

The standard operation for the indoor positioning relies on ‘blink’ signals being sent by mobile units as presented in Fig. 3 and received by stationary bases fixed in permanently within the building with known positions. Those positions may be either relative to the building or with some additional processing converted into absolute spatial positions compatible with GNSS systems.

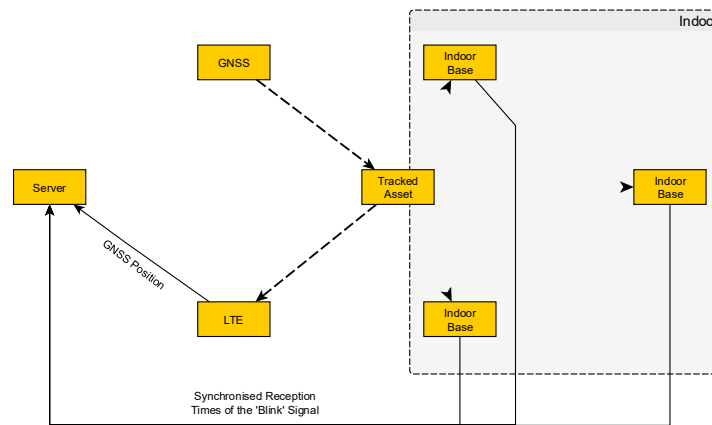


Fig. 3. A schematic describing the relation of GNSS positioning and UWB positioning with the use of bases of known locations; those locations could be either used as relative to building internal architecture (relative) or WGS84 compliant (absolute), as used by GNSS receivers; Indoor zone on the schematic here is one section only, with two bases synchronised to the one acting as a primary over one network

Source: own work

As all bases required to be synchronized, the system inside the building can use one of two possible options:

- a) separate networks (subnetworks) for each separately defined area, with a single device per one network which acts as a local synchronisation source (master) for other elements of this network (slaves)
- b) one large network of bases each synchronised with a very accurate (highly stable) common source using Precision Time Protocol. This is necessary as for a proper estimation of ranges the bases must rely on very precise synchronisation between their internal clocks.

For our test we used first a solution with local synchronisations as the general indoor method in areas that are relatively small one unit is selected as the master the other units in range (slaves) synchronise their times to.

Once synchronisation is complete under network each tracked device can send signal which is received by the base and is then rerouted to the server. Upon reception if the new packet the server performs identification how many data had it received that would match the individual ID of the packet in that network. Once three separate data of the packet have been identified the system performs calculation of the apparent position based on the positions of the bases and time required for the data to be received by at least three bases. Based on that information it is possible to estimate the position of the tracked signal emitter.

### Emergency backup system for redundant positioning of outdoor assets

The basis for the system to be used outside in case primary method (GNSS) would not be available are two concepts which would shape the solution aspect: first, a system that as in case of indoor solution uses fixed elements embedded into the structure of the equipment standby zones on the airfield itself and synchronised to the server through PTP. This solution is more complex as the reference elements fixed in position (non-movable, permanent locations) within the operational area would have to be protected and furthermore would require additional infrastructure to be fully

operational (power, communication with server). Furthermore the would have to be protected in the typical operations within the operations field on aircraft standby zones.

The second option would use dynamic setup of elements, to switch operation on of the DW1000 modules on assets that can also be tracked but remain stationary, to enable operation as a temporary fixed bases. As typically an outdoor system would utilize GNSS tracking as main positioning system, the UWB system would only by activated in case GNSS detects jamming or spoofing. Jamming incidents are easy to be qualified as the receivers would simply lose the ability to produce valid positioning results (LoS). Spoofing on the other hand would be detected by identifying discrepancy in GNSS locations registered within a complete group of tracked assets.

Incidents will be identified by analysing the position registered by the GNSS receivers upon stationary assets. Furthermore assets close to indoor operational area of the system would still be able to position themselves using GNSS and UWB systems independently and compare both results. In case stationary units register significant differences in positions as time-series while UWB positions remains constant (minimum discrepancy), this enables alert regarding the possibility of GNSS system being attacked by spoofing. This event would essentially switch operation of GNSS positioning into monitoring mode, while the rest of the system would switch to operate by the use of UWB method solely with general positions being converted from relative (building relative) to absolute (WGS84 used by GNSS). Therefore system is capable of making long term GNSS to UWB positioning relation that enables the system to check if the results are within tolerance and system can go back to rely on GNSS and send positioning information in WGS84 format, as used by the system.

Because the employed receivers do not provide precise enough time-pulse signal to directly synchronise times among bases, the prime mode of operation for UWB based solution is therefore a local synchronisation over master-slaves as similar to the aspect of the system used indoors. In this option a central processing unit which is a server, analyses the spatial information of the mobile bases and their movement in real time. In case a GNSS position becomes unavailable (jamming) or is significantly altered (does not correspond to typical positions or position understood as time series) the system automatically selects assets that prior to identifying spoofing attempt were stationary and selects their previously calculated positions as references with enabled UWB positioning. This position can be additionally integrated from more than one measurement if the devices were stationary.

However, since the bases are stationary only for a certain time, the system is required to dynamically re-shape the UWB network configuration (switching some bases into tracked mobile assets, and tracked units back into stationary references) to:

- maintain synchronisation among the maximum number of devices with minimum subnetworks possible,
- based on information about the movement system is also capable of selecting alternatives in case primary selected assets working as temporary inert bases need to be switched to further support positioning at certain area.

UWB units can also provide a more robust, but more power consuming mode of operation that utilise two-way ranging (TWR), which has an advantage over TDoA that it does not require bases to be synchronized. Therefore, the system – if utilised with some, now static, UWB units – can theoretically maintain activity, even in case of GNSS signals and synchronisation within dedicated set of assets being unavailable. However, the downside is that it is the server that controls the ranging

requests to target devices, which requires some time for completion and therefore must utilize some form of bases selection logic and queuing to prevent request collisions between devices over wide-band communication. Furthermore TWR mode might be problematic in a sense that it would be hard to implement if all bases alongside tags are non-stationary. However, in our example case we assume that at all times a certain number of assets remain stationary which simplifies operation as we take the last known and valid position from GNSS.

Furthermore, UWB technology which is by definition wide-band is generally less prone to jamming, because of the nature of the signal spectrum. It also means that the signal is less likely to influence other systems with narrow-band data transfer. In typical operational scenario, the GNSS units provide positional information as a required spatial reference, which is obtained via wireless link (typically LTE) by the central processing unit. This unit maintains a snapshot of current active units positions, an information that self-updates as new data are being sent to server. Server also actively selects mode of operation for the dispersed elements of the system, prioritizing non-moving units as reference bases with known locations. Therefore an active system always maintains some temporary inert assets as active reference bases for supplementary UWB positioning.

The moving units that rely on UWB technology, which do not have the direct positioning capability send 'blink' messages periodically. Those messages are received by the active units that use both GNSS and UWB modules with a identification key. The received signals are detected at certain times on mobile units which contain enough information to recreate in-sync timestamps through linear interpolation. Those data include timestamps for arrival times which are then sent back to the central processing unit. The unit, which is a server, takes the positioning information provided by the GNSS snapshot for mobile units and uses it as a reference in TDoA calculations based on calculated signal arrival times as registered by timestamps on those active devices. The algorithm then calculates the possible candidates for position for each tracked unit.

The results are then verified with the expected input ranges for each candidate which allows errors to be subtracted from the poll. The remaining results are then merged into one single position for each tracked unit, using weighted averages. This result is therefore the most probable solution for each passive asset tracked. This served as the baseline for further estimation. The system retains the original capability of the initial Ground Eye solution, which is to operate independently, without the aid of the airport infrastructure and in same time, potentially provides more than one possible mode of operation (additionally to positioning) as the secondary UWB network also can act as a data-transmission layer. Therefore, it can provide backup capabilities to either one or both components – communication layer and positional awareness layer. However it is expected that without external reference for the UWB units the positional information may be prone to rising errors and overall precision degradation in results as the units are in motion and units often switch operation from base to moving asset and vice versa. That is why it is preferred for the reference units to be stationary when operating as bases for UWB positioning and the most fitting approach would be to for each monitored field of operation have at least three fixed point units used only as reference backup. For each set up network in a remote area at least three devices need to be set up to provide spatial coordinates (reference used to calculate positions of the mobile units), but system can provide some limited spatial awareness with even single reference device, which limits positioning to range from the base station. With two bases system can produce two possible solutions and the final, proper position be calculated

by discarding the result which is impossible due to operational constraints or is just less likely when compared to typical operation or by testing it against the time series positions.

Furthermore system can also be active alongside GNSS positioning to provide a double layer of information which then can be used to verify the current state of GNSS positioning as the GNSS positioning and the position obtained by the UWB system should correspond to each other (with set static reference bases). Significant difference in obtained positions should indicate the probability of system spoofing mostly on the side of GNSS. However other approaches are also available [5].

### **Positioning tests using the UWB units**

The initial positioning tests have been performed using the UWB setup, with calculation layer being done using Python scripts. The bases positions have been calculated using TWR method, with system upon completion switching operations into TDoA mode. The initial TWR is only used for properly calculating bases positions and obtaining the resulting propagation delays between master and slave bases. The TWR method is therefore used because it can work without proper synchronisation of bases and the synchronisation cannot be achieved without knowing the precise position of bases which directly influences the delay of signal reception time.

In order to properly calculate position of the tracked object, the system collects information from the signal receiving bases and performs analysis of the reception times and signal iteration identification. The signal iteration identification must be common among the bases – this solves the problem with multiple signal sources as the identifier will be unique per device and also the signal source identifier would be the same as well.

This essentially mean that if at least three bases in the network have at least three independent data points with same iteration ID and same source ID, the system can use remaining data to calculate absolute, proper signal reception times as referenced by the master base. The error range for this system during testing was within 10 centimetres. In case more bases are available within the range of tracked device, the system can calculate a set of most probable positions which would then be used together to form the output position most likely associated with tracked unit.

Tab. 2. Measured distances via TWR method between bases; system is capable of making multiple measurements and stacking them together achieving mean value; all values in m; deviation is understood as difference +- towards mean value

Source	Target	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Mean	Deviation
0x0001	0x0002	1.44	1.42	1.35	1.39	1.38	1.38	1.39	1.40	1.37	1.40	1.39	0.03
0x0001	0x0004	4.54	4.52	4.27	4.29	4.27	4.30	4.27	4.27	4.32	4.36	4.30	0.10
0x0001	0x0005	2.53	2.55	2.43	2.53	2.54	2.54	2.55	2.51	2.52	2.56	2.54	0.04
0x0002	0x0001	1.46	1.44	1.34	1.35	1.35	1.39	1.38	1.38	1.37	1.35	1.38	0.04
0x0002	0x0004	2.75	2.73	2.65	2.71	2.71	2.71	2.68	2.69	2.73	2.72	2.71	0.03
0x0002	0x0005	2.04	2.06	1.92	2.01	2.00	2.00	1.98	2.00	2.04	2.01	2.01	0.04
0x0004	0x0001	4.48	4.52	4.23	4.28	4.25	4.31	4.31	4.28	4.30	4.29	4.30	0.10
0x0004	0x0002	2.72	2.72	2.62	2.72	2.68	2.69	2.67	2.67	2.67	2.70	2.69	0.03
0x0004	0x0005	2.92	2.85	2.89	2.94	2.87	2.87	2.91	2.91	2.91	2.87	2.90	0.03
0x0005	0x0001	2.49	2.47	2.45	2.51	2.52	2.51	2.50	2.50	2.54	2.51	2.51	0.03
0x0005	0x0002	2.00	2.00	1.93	1.98	2.02	2.00	2.01	1.99	1.98	1.99	2.00	0.02
0x0005	0x0004	2.88	2.92	2.87	2.92	2.89	2.84	2.92	2.90	2.88	2.89	2.89	0.03

Source: scenario with devices in testing architecture

System capabilities have also been evaluated by taking the readings from the GNSS system and estimating the possible reference position errors and then using that base positions in order to calculate TDoA position of the simulated signal. To do that system knows the proper, correct locations (directly from the GNSS) and then administers positioning error into that information as defined by the distance. Resulting positions of the bases are being used as reference, therefore positions calculated by the system for tracked assets are based on TDoA method (reception times) and will include this timing error.

The TDoA information and the positions of the bases are then used similarly to how the indoor tracking system uses to calculate estimated location, with exception to calculated bases positions, which in case of the simulation are taken from GNSS information and processes into local reference. Thus the position data provided is being used to calculate distances between master base and slaves which are then used to ascertain the propagation delays required to calculate proper signal reception times referenced to master. This information when presented within the frontend application needs to be recalculated into WGS84 as used by that frontend system.

This allows the simulated information to formulate error response value as defined by the embedded errors in synchronization (as based by the UWB system) and errors in the base positions (which include positioning errors as defined by GNSS model). With proper synchronization the GNSS positioning error carries more weight into achieved positioning result.

## Conclusions

The tests proved that the system is capable of tracking assets within the terminal as expected with the use of additional, secondary positioning system based on UWB principle with highly accurate time synchronization. This enables all tracked assets to be also visible when transferring from outside to indoor use and also to provide backup in case assets works in the vicinity of the large terminal or

hanger buildings which could introduce positioning discrepancies from the GNSS point of view. Furthermore the system seems capable of being implemented as well as backup in order to provide positioning capabilities on the standby zones and aircraft slots on the airfield itself either by using temporarily static assets as temporary bases or separate a set up devices used permanently as backups. The set up units working as backups clearly are less problematic when compared to temporary bases, their implementation might be more demanding because they would have to be embedded within the operational fields on the airport itself.

However, with the large number of assets working in the same area it is generally accepted that a certain number of equipment could be used as stationary reference to provide baseline for independent positioning calculations, because simply not all assets are being used at all times or rather not all assets are moving. In fact, a typical asset operation suggest that most equipment usually is stationary and only moves when it's necessary to reach new destination, either a standby point or a service slot near aircraft.

To be absolutely certain, a better solution would be for a system to either lock some assets until the GNSS method of positioning becomes available again or perform dynamic change of slaves with one temporary base used as master. Then the change of secondary slave from one asset to the other would simply require to change the identification of slave and to calculate the required propagation delay. In typical daily activity however a secondary positioning system would be mainly used for positioning only within building and possibly close to buildings to mitigate positioning problems with large area of the sky being blocked with the buildings themselves. Also it is important to note that GNSS jamming is the primary problem that this system is designed to solve.

The more problematic attacks over the GNSS systems like spoofing, with the initial location being close to real positions with discrepancy being introduced slowly over a certain time might be hard to track without the expected, permanently embedded bases within the standby fields or aircraft slots. As those units could have fixed positions they can serve as GNSS monitoring stations to inform the main system about possibility of GNSS location being unreliable by comparing the saved positions of those inert bases with obtained live position from the satellite navigation source. Rising discrepancy between saved, correct positions of the bases and GNSS provided positions can provide input over information if the system is being spoofed and possibly also over what area. Other indication might be the positional analysis of all tracked units and identification of positions that are outside the declared operational bounds of the airport. In any case, visualisation systems and most notably IoT systems are necessary for the proper control of the assets within the airport [6].

Our analysis shows that the UWB bases could be used reliably as the secondary positioning system in case GNSS fails and with the positioning errors within the tolerance, especially if the GNSS provided reference positions are highly accurate, stressing the need for a proper RTK enabled positioning or by containing fixed, permanent secondary reference bases within the airport operation slots, so that the position for those units could be set up permanently as they would be inert over time.



Fig. 4. A application frontend screen showing the positions of aircrafts and tracked assets in a typical operations mode  
 Source: own work

Additionally a visualisation segment has been tested in real time operations and furthermore as the visualisation for simulated data. The example of the working frontend used for visualisation can be seen on Fig. 4. In both cases the system proved to be reliable and provided proper positioning information about selected assets in real time. Furthermore system has been designed to incorporate visual information about several common classes of aircraft which can be further enhanced to include spatial information about designated standing point for a classes of equipment which can be used a position verification layer in planned more advances system which could issue individual command to assets to move into designated slots. This essentially allows the system to be used in the future with command and control terminals within tracked assets to inform operators where and when exactly those assets in question would be needed. Furthermore, this solution can potentially be used with autonomous equipment, with system being responsible for setting proper places for certain equipment to be used as standby point or as service slot, as defined by the aircraft class.

The visualisation system can also be used to gather information about approaching aircraft by utilising the ADS-B information in close to real time using either access to online service or local ADS-B compatible receiver.

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# THE EXTENT OF THE IMPACT OF VARIOUS INDICATORS ON THE IMPLEMENTATION OF RENEWABLE SOURCES AS GRASPED BY THE STUDY OF THE PODKARPACKIE PROVINCE

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## **Abstract**

The purpose of the article is to identify and discuss indicators affecting the implementation of renewable energy sources in the perspective of the Podkarpackie province. To achieve the goal, a qualitative and quantitative study was designed, which employed the following research methods and techniques: analysis of foundational data, a follow-up survey in the form of interviews with authorities and community organizations plus qualitative individual in-depth interviews by telephone (TDI) with residents in the form of a questionnaire using the CAWI technique. The article identifies selected indicators, a form of differentiation of phenomena by objective, measurable factors and various impacts of RES implementation. The following instruments were studied: subsidies, support programs, loan concessions and their impact on indicators: socio-cultural, knowledge and environmental awareness, social acceptance of photovoltaics or even traditions and cultural values in addition to attitudes towards innovation and technological solutions. The article is a valuable starting point for further RES research.

## **Keywords:**

*renewable energy sources; photovoltaics; RES implementation indicators; qualitative and quantitative research*

## **Introduction**

In the era of rapidly changing energy realities, resulting from the growing need to decarbonize the economy worldwide, as well as in response to rapid climate change, renewable energy sources (RES) have become a key component of energy policy at both the national and regional levels. As a member of the European Union, Poland is obliged to meet ambitious targets related to reducing greenhouse gas emissions and increasing the share of renewable energy in the national energy mix. In the context of the Podkarpackie Province, whose geographic, demographic and economic peculiarities create unique conditions for the development of the RES sector, special attention should be paid to the implementation of new photovoltaic technologies.

According to the current national energy policy, the implementation of renewable energy sources, including primarily photovoltaics, is one of the top priorities. These activities are part of a broader energy transition strategy aimed at reducing dependence on fossil fuels and improving air quality. The Podkarpackie region, despite its agricultural nature, has significant potential for solar energy development. However, the region also faces specific challenges related to infrastructure, land availability and regulations that may limit RES development.

This paper will present an analysis of the current status of the implementation of renewable energy sources, with a particular focus on photovoltaics, based on own research conducted in the Podkarpackie Province in the period 2022-2024. The aim of the study was to present the impact of energy policy in Poland on the implementation of RES projects in the region and to identify the most important challenges related to their implementation.

This study will also consider social and economic aspects, such as the impact of RES development on local communities, jobs and energy costs. Both qualitative and quantitative methods were used in the analysis, as well as foundational data. A sample of N=208 was surveyed, using a variety of research techniques, including analysis of data from government reports, interviews with representatives of local authorities, community organizations and residents. In addition, examples of specific investment projects implemented in recent years in the province were included, particularly in the area of photovoltaics, which is closest to the author of this publication.

An analysis of energy policy in Poland points to three key examples that have had a significant impact on the development of RES in the Podkarpackie province. First, national support programs for the development of photovoltaics, such as *My Current* and *Prosument*, have laid the groundwork for widespread implementation of photovoltaic technologies in urban as well as rural regions. Second, the cooperation of local governments, such as the Marshal's Office of the Podkarpackie province and the Rzeszow City Hall, with NGOs and community organizations, has helped to increase public awareness of RES. Third, activities in the area of infrastructure adaptation and the creation of conditions for investment, by eliminating administrative barriers, have been crucial to the implementation of renewable energy solutions in this study region.

The aforementioned challenges related to infrastructure, land availability and legal regulations may be significant constraints on the further development of RES in the Podkarpackie province. Examples include the difficulty of obtaining appropriate permits for the construction of photovoltaic farms in protected areas, as well as the problem of access to electricity grids in less urbanized areas. In addition, changing legal regulations, related to RES laws and their implementation, may affect the pace of development of this sector in the region. The article will discuss the social and economic aspects associated with the development of the RES sector in the Podkarpackie, including the impact on job creation in the RES industry or lowering energy costs for households.

Given the peculiarities of the Podkarpackie region, the article will present details of RES implementation in this region. Conclusions of the research and analysis of energy policy at the national and regional levels are an important contribution to the further development of RES strategy in Poland, especially in the context of regions with specific geographic and social conditions.

## Characteristics of the Podkarpackie province

The Podkarpackie province under study is a unit of administrative division of Poland, it is one of 16 provinces created in 1999 in our country. It was created by merging the Przemyśl, Rzeszów and Krosno, Tarnobrzeg and Tarnów provinces. The province has an area of 17,845.76 square kilometers, and in terms of population it has about 2.09 million people. It covers an area of 1,784,573 hectares (17,846 km<sup>2</sup>), which is 5.7% of the area of our country. The largest cities in the Podkarpackie province are: Przemyśl about 66,000, Stalowa Wola 63,000, Mielec about 60,000, Tarnobrzeg about 50,000, and others with less than 40,000 inhabitants.

With regard to the subject of this article, it should also be reported that electricity consumption per capita in the Podkarpackie was in 2022 = 549.6 kWh. In the years under study, the highest level of electricity consumption per capita in the Podkarpackie was recorded in 2020 with the result of 607.9 kWh, and from 2021 there was a noticeable decline in energy consumption. In terms of this indicator, the studied the Podkarpackie province was in last place among provinces in Poland in all the analyzed years.

Today, the Podkarpackie region surveyed is visibly leading the way in the number of new photovoltaic installations per individual household. Despite the lower level of affluence, the residents of this region are the most involved in RES investments. The strong commitment of local authorities is evident here. Between 2014 and 2023, as many as 117 projects co-financed by the European Union were implemented in the Podkarpackie Province to implement RES. Thanks to the survey, it also turned out that the Podkarpackie Province is also the most active in launching educational and informational initiatives, which is evident in the data on the amount of funds spent under the *Regional Support Program for Environmental Education*. The examined budget for the implementation of educational projects within the framework of the available program in the Podkarpackie Province was equal to PLN 3,500,000, which meant that an amount of PLN 5.84 of this education and training budget was spent per inhabitant of the province.

The region, as proven by the survey, is also very well prepared from a technical point of view, as evidenced by the rather low number of grid connection refusals recorded in 2022 because only 250 applications were rejected. In addition, interestingly, the largest number of investments in new electricity grids are planned in it.

## Outline of the Podkarpackie province

In the Podkarpackie Province, the number of electricity consumers in households in 2022 was = 758.6 thousand. All information about the call for new RES programs is available from the Podkarpackie Province Board, which is the Managing Authority for the regional program from the European Funds for the Podkarpackie for 2021-2027, this office is based in Rzeszów. He is the one who always announces all calls for applications for financing the implementation of given projects in a non-competitive mode, such as from the European Regional Development Fund, which operates within the framework of the regional program *European Funds for the Podkarpackie province for 2021-2027*. Today, you can apply for the following measures such as: Priority FEPK.02 for Energy and Environment and Measure FEPK.02.04 for Renewable Energy Sources - IF. In the Podkarpackie Province, a *Program for the development of renewable energy sources* has been established and is

operating quite efficiently. The Board of Directors of the Podkarpackie Province has adopted this program for the development of renewable energy sources, and thanks to this local entrepreneurs will know where to locate RES investments. The adopted strategy of the program is a very important development document for the region. This program indicates exactly in which districts of the Podkarpackie there are the best conditions for investing in RES. The solar energy development will be most efficient in the districts of Rzeszow and Mielec.

However, when it comes to green energy, the Podkarpackie has EU support with subsidies for such investments, which increases interest in this topic not only among various farms and institutions in the Podkarpackie. Thus, for example: The University of Law and Administration in Rzeszow has launched the largest installation of photovoltaic cells in Poland - a huge solar battery that reheats buildings in winter, and in summer allows for air conditioning or cheaper lighting. Further RES investments are also in operation in the system for reheating swimming pools in Debica and Glogow Malopolski. The Podkarpackie universities and local government units, schools and business institutions have joined forces to create a platform for RES cooperation. *The Podkarpackie Renewable Energy Cluster* operates as: *The Podkarpackie Ecoenergy Association*. These are energy producers, solution providers for the entire energy industry, as well as installers of systems in the renewable energy area. Another representative of business environment institutions in activities for the new RES is the Podkarpackie Energy Agency.

## **Own study methodology and the forms of its conduct**

The purpose of the research conducted in this study was to discover and describe regional renewable energy implementation indicators from analyses of self-reported data for the Podkarpackie Province. To achieve the stated goal, I decided to use the research and qualitative method (Glinka and Czakon, 2021) [1]. The qualitative research involved the collection of the required data through my own interviews and analysis of foundational/secondary data, which was *desk research*. The primary research took the form of follow-up interviews with local authorities of specific offices and community organizations. This classic qualitative research, was conducted in the form of individual in-depth telephone interviews (TDI) and through interviews with selected residents of the Podkarpackie region, which was conducted form, as a questionnaire survey using the CAWI technique. The analysis of all collected data for the article in the form of found data included a wide variety of data sources such as those that at the time of writing were current and readily available for the purposes of this article, and these were mainly: public statistics (mainly data from the CSO portal), available reports from central government offices or important local ones, obviously responsible for the Polish energy market. With the assumption that these are data collected from programs supporting the development of new RES or green energy, as well as available reports from major energy and even installation companies in the subject under study for the Podkarpackie region.

Details of the methodology for the research used in this article. The following known research methods and techniques were used to achieve the intended objectives of the article:

- 1) extensive desk research (desk data analysis),
- 2) qualitative follow-up survey with regional authorities and community organizations individual in-depth telephone interviews (TDI),

- 3) the quantitative survey of regional residents is a questionnaire survey using the CAWI technique.

The desk research analysis assumed a detailed thorough analysis for the available collected data. This analysis of found data, from the point of view of achieving the objectives, was the main and basic stage of the work, allowing to answer the key objectives. It also made it possible to formulate and plan the detailed issues addressed in the in subsequent parts of this study, such as: developing follow-up scenarios for individual in-depth telephone interviews (TDI) and the questionnaire for the quantitative survey of the Podkarpackie residents using the CAWI technique.

Adopted for the purpose of the assumed objective, the analysis of the collected foundational data included a variety of data sources such as: public statistics (e.g., CSO data), reports from central and local government offices and local authorities responsible for the energy market, data from the largest known programs supporting the development of green energy in Poland, and available reports from energy or installation companies currently operating in our country.

The CAWI (Computer Assisted Web Interview) quantitative research method involved measuring found attitudes, phenomena and opinions using a standardized questionnaire. The CAWI technique, or computer-assisted online interviewing. This survey was conducted on the ARIADNA National Research Panel. It was a research panel with more than 300,000 consumers aged 15 and above registered today. Each surveyed panel participant is subject to constant verification and is guaranteed full anonymity and confidentiality of personal data. The panel is certified by the Polish *Quality Control Program and Work of Interviewers* (PKJPA) in the category of CAWI surveys. It is obtained on the basis of a quality audit conducted by the *Organization of Public Opinion and Market Research Firms* (OFBOR), which always guarantees that each survey is conducted in accordance with applicable Polish research standards. The present survey was conducted on a total sample of residents of the Podkarpackie region (N=208). The research sample used was of its own nature: a purposive-quota sample corresponding to the structure of urban and rural residents in the studied province.

## Study results

In the Podkarpackie province, individual photovoltaic installations should be related to the natural potential, which is the number of households. Comparing the number of all photovoltaic installations set up under, for example, the *My Electricity* program, it is the Podkarpackie province that should be singled out here as the RES leader for individual photovoltaics. In this surveyed province, as many as 7.1% of households have this type of installation. In this very province, per surveyed household there is an installation with an average power of 1.4 kW. Taking this ratio of the power of photovoltaic installations (MFIs) to the number of households in the Podkarpackie, I made a comparative analysis of the in which other provinces in Poland were taken into account. And this is where Podkarpackie province has the highest ratio of power to the number of households owned.

Delving deeper into the analysis, in 2018-24, the *My Electricity* program granted 514,479 subsidies across Poland, and in the Podkarpackie Province, 42,796 applicants benefited from the program's subsidies. Thus, in terms of the number of applications to the number of households in the province, the Podkarpackie is a visible and clear leader in the country because per 1 subsidy here was 0.071 households. Going further in the analysis, the total capacity of photovoltaic installations financed under the *My Current* program Poland is 2,378,938,153W, and the total

capacity under the program in the Podkarpackie province is above average because it is 184,415,759W (where 148,683,635W is the average in Poland). By converting the power of photovoltaic installations to the number of households, the Podkarpackie province becomes the leader of the My Electricity program with 307W per household. Further analysis of the results was based on individual indicators, which I will write off one by one.

### **Utilization rate of *My Current* program funds**

The first indicator to compare the use of funds from the *My Current* program is the number of households per subsidy from this program. Analyses have shown that the highest number of investments made under the *My Current* program is in the Podkarpackie region.

### **Cofinancing rate of measures in the *Clean Air* program**

On the other hand, under the government's *Clean Air* program, since the beginning of its operation (19.09.2018) more than 151 thousand applications in Poland were received for the amount of funding of about PLN 3.1 billion. For 2024-2029, the government under the European Funds for Infrastructure Climate Environment (FEnIKS) planned to co-finance the *Clean Air* program with the amount of PLN 6.4 billion, which gives in this plan in the Podkarpackie province the possible distribution of the amount = 486 million PLN in subsidies. Thus, for the period 2024-2029, the refinancing of projects in the studied the Podkarpackie Province with the amount of PLN 486 million allows to place this region slightly above the national average (PLN 400 million). In further conversion of this amount, here the amount per household will be PLN 810, which again gives the second highest result in Poland. Inferring further, the planned subsidy will favor the development of photovoltaics in the Podkarpackie.

### **Indicators of other support programs**

Today, the Podkarpackie Province benefits from other regional programs that support the development of RES: these are loans for RES support from European Funds. As part of the implementation of the *Loan for RES support* in the studied Podkarpackie province they are planned with the assumptions of obtaining additional capacity to generate new electricity from renewable sources, which should reach = 59.2956 MW, and additional capacity to generate new thermal energy from renewable sources should reach = 1.8824 MW (at the level of the indicator of the given product). Importantly, it is planned that the new electricity generated from renewable sources should form the upper level = 59,295.60 MWh/year, and the new thermal energy generated from renewable sources should be at the upper level = 1,882.40 MWh/year (at the level of the result indicator). Thus, the use of new RES will be an important element in decarbonizing the economy in the Podkarpackie Province and in diversifying the sources of new energy generation. Most importantly, due to such a positive impact on the environment, this project will be a major contribution to the country's sustainable energy transition aimed at a low-carbon economy, in line with the policy of sustainable development of Poland as well as the EU. The value of this project = PLN 369,470,117.65, and the amount = PLN 314,049,600 are grant funds from the European Union. Another important step in the Podkarpackie region is *Loans for Improving Energy Efficiency* financed by European Funds. As part of the implementation of this project the following are planned:

(a) loans for improving the Energy Efficiency of micro and small businesses

and

(b) loans for improving Energy Efficiency in the residential sector and public buildings, as well as upgrading street lighting.

A minimum of 74 enterprises and 594 residential units and= 9,926 m<sup>2</sup> of public building space will be supported to improve Energy Efficiency in the Podkarpackie region. The aim of this project is to improve Energy Efficiency in the Podkarpackie micro and small enterprises (through energy recovery in the production process, energy modernization of buildings with the installation of RES equipment), in the residential sector and public buildings (which can be complemented by the installation of RES equipment and the replacement or modernization of heat sources or connection to a new network heating or cooling) and the modernization of street lighting in the Podkarpackie. These activities are consequently expected to reduce air pollution and the emissions for greenhouse gases. The value of this project = PLN 170,607,106.52, and the amount = PLN 145,016,040.54 is from direct subsidies from the European Union.

This indicator compares the amount of regional RES loan funds per household from regional funds. A relatively large amount of loans from regional funds for RES purposes was distributed just in the Podkarpackie Province, where this result = PLN 900.44 per household. Regional *RES Support Programs* are loans for RES support and energy efficiency improvements, which were characterized in the Podkarpackie Province by the largest number of beneficiaries and installation capacity, the highest planned financing with significant support from regional loans.

### **Cultural indicator**

The interviews being part of the survey included the opinions of representatives of local authorities and organizations in the Podkarpackie province speaking the first time about cultural issues, specific to this region, which determine the approach of residents to innovation, investment, improvement of living conditions. Summarizing the results of this survey in the field of access to information and education, it can be seen that the Podkarpackie province is in a good position, because the residents of this region best evaluate the availability of information and its quality. It is also evident that a better educational and informational offer is linked to greater interest in new RES or involvement in the subject of new photovoltaics.

### **Socio-economic structure indicator**

The studied socio-economic structure, including the income of the Podkarpackie society or the availability of financing and ownership structure affect the ability of households, businesses to invest in new photovoltaic technologies. There are clear regional differences here in terms of wealth, which have a direct impact on the ability to invest in RES. Studying and based on current CSO data on household incomes in 2022, we can distinguish the Podkarpackie province, where they are apparently the lowest in Poland and amount to only= 81.3% of the national average. The examined socioeconomic structure, including earned income and access to good RES financing affect the ability to invest in modern RES. In the Podkarpackie province, despite the lowest income (81.3%), there is, as this study has shown, a high interest and involvement of residents conducive to the willingness to implement new RES.

### **The Internet access and smartphone possession rate**

According to data from the Central Statistical Office for 2022, 87.9% of households in Poland have access to the Internet. On the scale of our country, 83.7% of households have a smartphone. From these analyses, the Podkarpackie region has a higher percentage of households with access to the Internet = 89%. In terms of smartphone ownership, the surveyed Podkarpackie province has a score = 87.8% and is second in the country after the Kujawsko-Pomorskie province. The surveyed Podkarpackie region, despite the lowest income for households has the highest indicators related to the implementation of modern technologies related to the Internet, mobile computing and photovoltaics. An indicator to compare the situation in the Internet availability is the number of households with such access. The demonstrated one of the higher number of households with the Internet access in the Podkarpackie region is shown to be one of the most favorable results in the country. Although slight differences can be seen in the data published by the Central Statistical Office (CSO) on the Internet access and smartphone ownership, it is safe to say that the surveyed Podkarpackie province is leading the way here [2].

### **Environmental performance indicator**

Based on the survey of regional residents, it can be concluded that residents of the Podkarpackie province have a greater awareness of ecology and environmental problems. This is evidenced by facts confirming that they care more about the environment through their activities, which they described in interviews than the residents from other provinces in Poland. Awareness of environmental problems also fosters acceptance of photovoltaics, which is confirmed in the results from the respondents, because here social acceptance of photovoltaics is more prevalent in the Podkarpackie Province, where most people see significant benefits of installing new RES installations. Residents in their own assessment are also described as ecologically engaged and aware of the need to modernize infrastructure. Ecology is very important here, as my respondents emphasized.

### **Public acceptance rate for photovoltaics**

Public acceptance of photovoltaics varies from region to region in Poland. Through a survey of Poland's regions, it can be concluded that the greatest interest in installing new photovoltaic panels was expressed by residents of the Podkarpackie, where the result = 43%.

### **Indicator of tradition and cultural values**

Traditions and cultural values have a significant impact on approaches to innovation and investment in new RES. In the Podkarpackie province studied, where residents have lived and functioned in the community for many generations, there is a natural interest in developing and modernizing their own homes, which encourages the adoption of environmentally friendly technologies. Their visible traditions and values push them to look for new solutions for RES.

### **Innovation attitude indicator**

In the survey conducted, residents of the Podkarpackie region also declare a positive attitude towards new RES technologies, and the result here was = 71%. Interestingly, urban residents are quicker to adapt to new RES technologies than rural residents in the Podkarpackie, which also affects regional differences in RES implementation relative to other regions of our country. Based on this

analysis, the Podkarpackie residents are considered to be willing to experiment with innovative solutions to benefit their households in the RES topic.

### **Access to information and education indicator**

Access to information and education are key to the implementation of new RES. In the Podkarpackie Province, the availability of information on photovoltaics based on the survey was rated fairly well according to respondents, with a tendency to indicate that the best is here in terms of the other regions surveyed. This assessment translates into an apparent greater interest and involvement in new RES. By examining what is the exact access to information and education on the subject of photovoltaics, it can be seen that it is significantly better rated here by respondents because education in the province on the possibility of using solar energy for photovoltaics, for example, is sufficient, which was confirmed to me by 37% of respondents surveyed. In the Podkarpackie area I also found the best accessibility to information on new photovoltaic systems with a score = 42% of respondents rating it as good or very good.

### **Indicator of the number of RES installers**

There are about 4,500 certified PV installers in Poland, registered by the Office of Technical Inspection. In my analysis, I included only installers with certificates valid today. Comparing the provinces in Poland and their total number of installers, it came out that the Podkarpackie province has = 304 installers. The Podkarpackie province also stands out in terms of the number of households per installer. In the Podkarpackie there are less than 2,000 households per installer because = 1973 households, and this is the best result in Poland after Lublin province with the number = 1951 households per installer. Thus, the availability of certified installers is shown to be one of the best in the whole country. The large number of installers of photovoltaic systems in the region will promote the increase in the number of new photovoltaic installations, and potential future interested customers for RES have easier access to professional companies, and the high competition in the local market is also conducive for them to obtain better purchase conditions such as prices for the installation or purchase of RES.

### **Indicator of direct investment in RES of local government units**

An important indicator in my research to compare the performance of photovoltaic installations was the number of direct investments in RES projects subsidized by European Funds implemented by local governments between 2014 and 2023. The biggest impact on the implementation of RES in the studied region has the local authorities of the Podkarpackie, as confirmed by = 53% of respondents. Residents of the Podkarpackie region were also the most active because they participate in programs and trainings on RES. As many as = 31% confirm that they have used or someone close to them has used RES programs, and = 24% have participated in trainings on the subject for new RES. Interestingly, the active participation of the Podkarpackie residents in RES projects was rated quite low. Thus, in the Podkarpackie province as the most involved, only = 25% of respondents rated it as high or very high. Similarly, the real influence on energy decisions was rated by respondents. Here again, slightly more residents of the Podkarpackie Province believed that it had a real influence, which was confirmed in the survey by = 17% of those marking answers rather yes and definitely yes.

### **Availability rate and quality of investor support**

The surveyed availability and quality of support for investors, for example, by qualitative or quantitative assessment for the incentives offered by the local government to investors in RES, including administrative simplification, advice, subsidies, tax breaks or other forms of financial support was analyzed in my survey. When surveying investor support from local governments, it was slightly better rated just in the Podkarpackie Province with a rating of = 31% for ratings of good and very good.

Summarizing the above-mentioned surveyed indicators, it should be clear that the Podkarpackie region is leading in the field of access to information and education on RES-related topics. As shown by the respondents, there is a clear connection between the best educational and informational offer with much greater interest and involvement in the subject of new photovoltaics in the area relative to the rest of our country. Summarizing the indicators shown, in the Podkarpackie province, leading today in terms of the amount of new photovoltaics in Poland per household, the highest environmental awareness and the highest acceptance of new photovoltaics were observed at the same time. It can also be seen that local authorities provide the best access to information on RES issues and photovoltaics. By which, at the same time, residents have positive attitude to all innovations and want to upgrade their own homes, despite the fact that economically they are less well-off than the rest of the country, as shown by statistics from the Central Statistical Office.

The implementation of new renewable energy sources (RES) in the Podkarpackie regional environment was strongly dependent on knowledge, skills and socially held values. After the analyses in my study, it can be concluded that the Podkarpackie province has clear - positive differences from other provinces, resulting from precisely these factors, which again affect the high level of adaptation and efficiency of RES implementation. Summarizing the Podkarpackie province and the figures, it should be said that it leads the way in the number of photovoltaic installations per household, which is certainly due to the high environmental awareness or the best accessibility to information and education, as well as the positive attitude of the region's residents to innovation. Despite the lower income, residents of the Podkarpackie region are the most engaged in our country in new investments in RES. Thus, the studied degree of knowledge, skills and socially held values have a significant impact on the implementation of RES in this environment of the Podkarpackie region, and the differences between other regions of the country are due to a combination of these factors and specific socio-cultural conditions, but showing smaller values.

To further explore the topic of RES in the Podkarpackie province, other conditions affecting renewable energy sources should be provided, e.g.: insulation, refusal of connections, grid access rate, and cost and profitability analysis of RES installations.

The first to be examined is insulation. The insulation of Poland is very similar to that of other Central European countries with similar latitudes. From the point of view of the possibility of using solar energy by photovoltaic installations, the most important parameter is the annual insulation value of a given area, which is determined by the amount of solar energy for a unit area of a plane in a certain period of time. By analyzing this parameter, it can be seen that the amount of solar radiation in Poland is characterized by a large regional variation because the density of radiation varies from 830 to 1051 kWh/m<sup>2</sup>. The best geographical conditions among the surveyed regions are in the

Podkarpackie province. Looking at the insolation data, the most favorable conditions in terms of solar radiation are in the Podkarpackie province, where it is = 1051 kWh/m<sup>2</sup>, as studied by Hewalex [3].

On the other hand, among other important conditions for RES are the so-called refusals, these are the data on refusals applying to all types of connections of RES generators to the electricity grid regardless of the size of the planned installation. It is worth noting that the situation regarding refusals varies from region to region. However, connection refusals increase the factual risk and perception of individual investors planning to build PV micro-installations. In the Podkarpackie region, the main reason for refusal to connect to the grid, according to respondents, was the demonstrated lack of technical and economic conditions with the result = 86% of registered cases. The so-called low refusal rate, in turn, favors further development of new photovoltaics in the areas of the Podkarpackie province.

Another factor shown in the study is the power grid access indicator. This indicator compares the availability of connection to the power grid through the number of refusals to connect to the grid in a given region. The study found that the least number of refusals to connect to the power grid was in 2022 in the Podkarpackie province. On the other hand, from an analysis of the cost and profitability of RES installations, data from the Central Statistical Office showed that the average rural household in Poland consumes about 2,500 kWh per year. The consumption of a rural household was assumed for the analysis, since single-family houses, on which photovoltaic panels can be installed, are predominant in rural areas. Thus, energy charges in the Podkarpackie Province were shown to be slightly lower than in other provinces of our country for example for the Warminsko-Mazurskie Province, and here they amount to an average of PLN 238 per month, which places the Podkarpackie province in the promising high scores for our country's RES [4].

## **A summary of the entire study and indications for the future of RES**

To provide a thorough summary of the study conducted in the Podkarpackie province, it should be mentioned that 40 new investments are planned here, including the construction or modernization of 25 substations and the construction of 9 new high-power transformers. One of the factors illustrating the experience of RES implementation in the studied province is the evaluation of the forms of photovoltaic installations in different parts and regions of this province and the number of installation companies [5]. In this regard, the studied the Podkarpackie province stands out, with 304 certified installers, while at the same time the Podkarpackie province has the lowest number of households per installer – 1973.

The Podkarpackie is also the most active in launching numerous educational or informational initiatives, as can be seen from data on the amount of funds spent under the *Regional Environmental Education Support Program* and the percentage of residents declaring participation in such initiatives [6]. The budget for the implementation of educational projects under the program in the Podkarpackie province = PLN 3,500,000 [7], which means that there is a PLN 5.84 education and training budget per resident of the province. This apparently translates into results, as= 24% of residents say they have participated in training on renewable energy sources. On the other hand, the examined activity of the local government in the field of education is reflected in the adequate sizable number of photovoltaic installations on the homes of residents, where the surveyed province was the leader. When deciding to invest in photovoltaics, residents also pay their attention to the energy potential of

these new installations in terms of the location [8]. The most favorable conditions of solar radiation are in the south in the Podkarpackie province, where up to 1051 kWh/m<sup>2</sup> can be obtained.

Similarly important factors shown through the survey were the availability of the power grid and its further development. And here, similarly, the Podkarpackie region also stands out in this area, with the lowest number of refusals to connect = 250 refusals to the power grid, and the most extensive new plans for infrastructure development = 40 investments. Analyzing the collected information from the surveys, the correlation of a higher number of households equipped with photovoltaics with a better quality of electricity infrastructure and at the same time with a larger pool of qualified installers is also well visible [9]. The survey leader is the Podkarpackie province, which additionally has the most investments planned in electricity grids and the authorities are the most active in organizing training and education programs that residents want to use. Between 2014 and 2023, 117 investments subsidized by European funds were implemented in the Podkarpackie province, which consisted directly of modernizing public facilities and local government infrastructure, as well as supporting local communities in implementing RES in households [10]. All projects were successfully completed. In the Podkarpackie province, projects whose beneficiaries were local government units focused on modernizing public facilities and retrofitting them with with RES sources, most often photovoltaics. In this province, local government units also supported the development of RES and photovoltaics itself in their subordinate areas within the framework of individual projects with funds for improving RES infrastructure in private buildings. The total amount of projects under which RES elements were implemented in the Podkarpackie province is nearly PLN 815,000,000 [11].

The Podkarpackie province is also at the forefront of individual photovoltaics because it is characterized by very high activity of local governments in investing or very good promotion of RES in their areas. Local government units today are not only investing in modernizing and upgrading their own public buildings, but also engage in projects that result in the development of photovoltaics among residents. Thus, they promote the idea of RES in every possible aspect of its importance to society [12]. Also, the amounts of completed projects were, as my research showed, very high. Instruments for the implementation of RES in the Podkarpackie region included programs and funds, such as *the Regional Operational Program of the Podkarpackie Province* and the national *Clean Air Program* [13]. Currently there are financial instruments, such as loans on preferential terms, to replace direct RES subsidies.

Promotional and informational activities regarding RES in the Podkarpackie include extensive information campaigns, training and meetings with residents, conducted by qualified personnel. Information has been and continues to be conveyed through various communication channels, including regional media and parish announcements. Local information campaigns and energy consulting by local governments and environmental funds are effective in promoting RES. As part of this survey, residents of the Podkarpackie province rated educational initiatives as best delivered because they scored = 37% from residents for the assessment that education in my province about the possibilities of using solar energy for photovoltaics, for example, is sufficient [14]. Availability of information on photovoltaic systems was rated best in my survey in the Podkarpackie province where the result = 42% of respondents rated it as good or very good.

On the other hand, conducted educational activities on photovoltaics were shown as the most effective also in the Podkarpackie province with the result = 60%, where the respondents believed that access to reliable information on photovoltaics increased their interest in the new investment in

RES technology. As can be seen through the survey, the effectiveness of such educational campaigns was also correlated with the power of photovoltaics in individual provinces, where of course the Podkarpackie province, which was the leader in the survey, held the first position.

Interesting results of the survey regarding the involvement of local authorities were assessed as well in the Podkarpackie province, which was also the leader in terms of the number of photovoltaic installations installed on residents' homes. Between 2014 and 2023, as many as 117 projects co-financed by the European Union were implemented in the province. They consisted directly of modernizing old public facilities and local government infrastructure, as well as supporting local communities in the implementation of modern RES in households. The level of local government involvement in such projects is correlated with the number of photovoltaic installations in residents' homes [15]. These activities are perceived by the surveyed residents as having the greatest impact on the implementation of modern RES in the region through the local authorities of the Podkarpackie region, which was confirmed by = 53% of the surveyed residents in the region. The involvement of the Podkarpackie authorities resonates with the involvement and needs of the local community because the residents of the Podkarpackie region were very active and willing to participate in all programs or trainings on the new RES, which was confirmed by = 31% of the people surveyed. This confirmation was based on the fact that they had used or someone from their immediate family had used such available RES programs. In contrast, already = 24% had participated only in training courses on this particular RES topic alone. These promotional and informational activities regarding RES in the Podkarpackie included extensive, various information campaigns, interesting trainings and meetings with residents, conducted by very qualified staff. Information was conveyed through various communication channels, including regional media, fire departments and even parish announcements [16].

The Podkarpackie region is also leading in the number of new photovoltaic installations per household. In this region we observe a very high environmental awareness, supported by the best among the surveyed provinces availability of information and education. Despite the lower level of wealth, residents of this region are the most committed to new investments in RES. The strong commitment of local authorities is evident. Between 2014 and 2023, as many as 117 large projects co-financed by the European Union were implemented in the Podkarpackie Province, which, it should be emphasized once again, concerned the implementation of RES. It should also be emphasized that the Podkarpackie Province is also the most active in launching educational and informational initiatives, which is evident in the data on the amount of funds disbursed under *the Regional Support Program for Environmental Education*. The budget for the implementation of these educational projects under this program in the Podkarpackie Province under study = PLN 3,500,000, which means that there is a PLN 5.84 education and training budget per inhabitant of the province. The region is also the best prepared from a technical point of view, as evidenced by the low number of refusals to connect to the network because in 2022 only = 250 applications were rejected. The Podkarpackie region also has developed quite a large and well-educated staff of photovoltaic installers because there are= 1973 households per installer, which is the best result among the analyzed regions in Poland. In addition, the largest number of investments in new electricity grids is also planned here [17].

As this research has shown, the cultural issues unveiled in the study are also important, e.g.: the community's attitude towards investing and improving their own living conditions in general. In the

Podkarpackie region, residents have lived and functioned in a given old community for many generations, so they are naturally interested in the rapid further development of their own homes towards modern RES directions and their entire surroundings where they live.

A good summary for my research on renewable energy sources in the Podkarpackie region with important indicators of RES development will be the projected forecast for the next few years for the region.

It should be noted that the Podkarpackie Province, in the context of the development of new renewable energy sources (RES), is paying special attention to photovoltaics, which is becoming the dominant source of renewable energy in the region. Government data shows that the number of photovoltaic installations in the Podkarpackie is growing rapidly, which is conducive to meeting local energy needs, as well as reducing greenhouse gas emissions. The increase in the number of photovoltaic installations also has a positive impact on the local economy, creating new jobs, especially in the solar panel installation and service sector. The economic aspect of RES development in the region also underscores the growing availability of EU and national funds that support green energy investments. The social benefits, in turn, include improved quality of life for residents, who gain a cheaper and more stable source of energy.

From a technological point of view, photovoltaics in the Podkarpackie region are benefiting from increasingly advanced solutions, resulting in increased efficiency of solar panels. In addition, the development of energy storage infrastructure is creating new opportunities for the integration of RES into the power grid, allowing for more stable management of new energy production. Moreover, the region is experiencing a visible intensification of research and innovation in building energy efficiency, which, combined with photovoltaics, is leading to a significant reduction in energy costs for end users.

Projections of RES development in the Podkarpackie region for the next 10 years may indicate a further increase in the share of solar energy in the energy mix for the region. It is expected that photovoltaic technologies will develop here, increasing their efficiency and reducing the cost of energy production. In the future, more widespread use of energy storage will also be possible, enabling better integration with the national power grid.

In the social sphere, educational programs and the environmental awareness of residents will foster even wider adoption of modern RES, which will further increase the number of photovoltaic installations. In the economic aspect for the Podkarpackie region, further development of the RES sector may become a key factor in the economic growth of the region, especially in the context of an increase in the number of investments in green energy and the related new jobs that are rapidly being created. At the same time, continued cooperation with the public and private sectors will be essential for further development of energy infrastructure and support for local RES initiatives.

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# QUALITY OF LIFE IN ONCOLOGICAL PATIENTS RECEIVING CHEMOTHERAPY

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## Abstract:

Chemotherapy, despite its beneficial therapeutic effects, is associated with patients experiencing mild and severe side effects that may directly impact quality of life. The aim of this study is to assess the quality of life of oncological patients receiving chemotherapy, taking into account selected individual and clinical variables. The research group comprised 100 patients from day chemotherapy units. The research instrument was the EORTC QLQ-C30 quality of life assessment questionnaire, supplemented with a demographic form containing additional clinical information. The examined group demonstrated varied results across different dimensions of functioning, global health status/quality of life, and symptoms accompanying the disease and treatment. The value of the described work is based on the utilization of a validated questionnaire and the consideration and description, in one place, of multiple variables that may potentially influence quality of life.

## Keywords:

*quality of life; chemotherapy; oncology patients*

## Introduction

According to the definition provided by the American Cancer Society, cancers constitute a group of diseases characterized by changes and uncontrolled cell growth, which may lead to the formation of nodules or masses referred to as tumors [1]. Currently, the incidence and mortality rates associated with neoplastic diseases are steadily increasing, ranking them as the third most common cause of premature death worldwide [2, 3]. According to estimates from the GLOBOCAN project, between 2022 and 2030, the number of new cancer cases is projected to rise by over 4 million, while the number of deaths will increase by more than 2 million [4].

Chemotherapy remains one of the most commonly employed conventional treatment methods for the majority of cancers. Pharmacotherapy based on cytotoxic agents is the most recent among the traditional oncological treatment modalities. Its development began in the mid-20th century, with significant advancements occurring at the turn of the 20th and 21st centuries [3]. Despite its beneficial therapeutic effects, a significant proportion of patients undergoing chemotherapy experience mild to severe side effects. It should also be emphasized that, according to current research, symptoms

resulting from treatment may tend to co-occur and exhibit interrelations [5]. Among the most commonly reported adverse effects of chemotherapy are fatigue, pain, loss of appetite, nausea, and vomiting, all of which can directly impact the quality of life of oncology patients [3, 6].

Quality of life (QOL), being a fundamental aspect of human functioning, is considered a paramount ultimate goal of medical intervention [7]. Currently, there is no unequivocal definition of quality of life. Existing conceptualizations assume approaches based on subjective well-being, human needs, beliefs, and personal experiences in the context of disease. Many studies emphasize subjective assessment as the primary component of quality of life, although there is also recognition of the importance of objective factors, which should likewise be taken into account [8]. An important issue often overlooked in quality-of-life research is the precise delineation of its definition and the distinction from other constructs used in the literature [9]. Among oncology patients, when referring to quality of life, we refer to health-related quality of life (HRQoL). One definition of HRQoL refers to the subjective perception of well-being, modified by the presence of disease and the implementation of therapeutic interventions [8]. It constitutes a multidimensional construct encompassing human functioning in three primary domains: psychological, social, and physical, all of which may be influenced by individual characteristics, socioeconomic conditions, and oncological parameters. According to existing research, the most significant individual and socioeconomic factors affecting health-related quality of life include gender, level of education, age, marital status, and socio-economic situation. Oncological parameters influencing HRQoL include disease duration, stage of advancement, type of cancer, and the treatment modalities employed [10].

The current oncological approach does not focus exclusively on pharmacological treatment but also incorporates a better understanding of the experiences of both patients and their families. This approach aims to optimize the allocation and management of available resources, focusing on achieving the best possible outcomes and ensuring holistic care that contributes to improving quality of life [11].

The objective of the present study is to assess the quality of life among oncology patients receiving chemotherapy, taking into consideration selected individual, economic, and oncological factors.

## **Materials and methods**

### **Study participants**

The conducted study included patients from two centers: the Świętokrzyskie Oncology Center in Kielce and the Provincial Specialist Hospital No. 5 named after St. Barbara in Sosnowiec. The study group consisted of 50 patients from the Świętokrzyskie Oncology Center and 50 patients from the Provincial Specialist Hospital, with various types of cancer, who were referred to the day chemotherapy unit in these facilities. The inclusion criteria for the study were as follows: (1) the presence of cancer, (2) chemotherapy as the current treatment modality, and (3) the participant's voluntary oral consent to participate in the study. The exclusion criteria included: (1) lack of the participant's consent to take part in the study and (2) a condition preventing the participant from understanding the questionnaire, which could result in inaccurate responses.

## **Research instrument**

The study was conducted using a questionnaire consisting of a demographic section supplemented with clinical information (type of cancer, stage of disease, and time since diagnosis), as well as the standardized quality of life assessment tool, the EORTC QLQ-C30. The data collection process was carried out personally by one of the authors through direct interviews. Prior to initiating the research procedure, verbal consent was obtained from each participant. The direct contact with patients and the administration of the questionnaire by the researcher enabled immediate clarification of any uncertainties, ensuring complete and coherent data collection.

The EORTC QLQ-C30 is a cancer-specific instrument designed to assess health-related quality of life (HRQoL) among patients with various types of malignancies. It consists of 30 items that evaluate five functioning domains (physical, emotional, social, cognitive, and role functioning), eight symptom scales (fatigue, pain, dyspnea, constipation, diarrhea, appetite loss, insomnia, nausea/vomiting), global health status and quality of life, as well as financial difficulties related to the illness. All items, except those assessing global health and overall quality of life, are rated on a 4-point Likert scale (1 – not at all, 2 – a little, 3 – quite a bit, 4 – very much). The global health and overall quality of life items are rated using a 7-point scale (1 – very poor, 7 – excellent). Scores are calculated according to the EORTC scoring manual and presented on a standardized scale from 0 to 100. Higher scores on global and functional scales indicate better overall health and quality of life, as well as higher levels of functioning. Conversely, higher scores on symptom scales indicate greater symptom burden [12, 13].

## **Statistical analysis**

The sociodemographic characteristics of the study population were presented using frequencies (n) and percentages (%). Other data were analyzed descriptively. Means and standard deviations ( $M \pm SD$ ) were calculated for each functional domain, global health status, quality of life, and individual symptoms as assessed by the EORTC QLQ-C30 questionnaire. Statistical analysis was performed using the Statistica 13 software and Microsoft Excel.

## **Research ethics**

Prior to conducting the study, a request was submitted to the Bioethics Committee, which concluded that no formal ethical approval was required for the study (Ref. No. BNW/NWN/0052/KB/171/24 dated 05.08.2024). Permission to conduct the study was also obtained from both institutions where data collection was carried out. No sensitive or personally identifiable data were collected during the study. The entire research process was conducted in accordance with ethical standards, respecting the rights and dignity of the patients.

## **Results**

### **Participant characteristics**

The sociodemographic characteristics of the study participants are presented in Tab. 1. The study included 100 oncology patients undergoing chemotherapy, of whom 37% were male and 63% were female. Patient age was categorized into four age groups: 41–50 years (10%), 51–60 years (12%),

61–70 years (42%), and  $\geq 71$  years (36%). The most commonly reported level of education among respondents was vocational education (43%), followed by secondary (37%), higher (18%), and primary education (2%). In terms of place of residence, the largest proportion of respondents lived in cities with populations exceeding 200,000 (35%). Regarding marital status, the majority of participants were married (60%), while individuals who identified as single accounted for 4% of the study group. Economic self-assessment revealed that the majority of respondents (53%) rated their financial situation as good, whereas only 6% described it as unsatisfactory.

Tab. 1. Socioeconomic Characteristics of the Study Participants

Socioeconomic characteristics		Group size n = 100 (%)
<b>Gender</b>	Male	37 (37%)
	Female	63 (63%)
<b>Age</b>	41-50 years	10 (10%)
	51-60 years	12 (12%)
	61-70 years	42 (42%)
	$\geq 71$ years	36 (36%)
<b>Education</b>	Primary	2 (2%)
	Secondary	37 (37%)
	Vocational	43 (43%)
	Higher	18 (18%)
<b>Place of residence</b>	Village	23 (23%)
	Town <50,000 inhabitants	28 (28%)
	City 51,000-200,000 inhabitants	14 (14%)
	City >200,000 inhabitants	35 (35%)
<b>Marital Status</b>	Married	60 (60%)
	Divorced	11 (11%)
	Widowed	25 (25%)
	Single	4 (4%)
<b>Economic situation</b>	Very good	29 (29%)
	Good	53 (53%)
	Satisfactory	12 (12%)
	Unsatisfactory	6 (6%)

Source: own calculations

Tab. 2. presents the clinical characteristics of the study participants. In the majority of patients, cancer was diagnosed within the last 12 months (68%), and the most frequently reported stage of disease progression was stage II (35%). Patients diagnosed with colorectal cancer represented the largest proportion of the study population (42%). The next most frequent diagnoses included gastric cancer (13%), lung cancer (11%), and breast cancer (10%). Smaller patient subgroups included those with pancreatic and liver cancers (6%), bladder cancer (5%), kidney cancer (3%), endometrial cancer (2%), as well as cancers of the palate and prostate (1% each).

Tab. 2. Clinical Characteristics of the Study Participants

Clinical characteristics		Group size n = 100 (%)
Diagnosis time	≤ 12 months	68 (68%)
	>12 months	32 (32%)
Type of cancer	Large intestine	42 (42%)
	Kidney	3 (3%)
	Bladder	5 (5%)
	Breast	10 (10%)
	Lungs	11 (11%)
	Palate	1 (1%)
	Prostate	1 (1%)
	Uterine body	2 (2%)
	Pancreas	6 (6%)
	Liver	6 (6%)
Level of advancement	Stomach	13 (13%)
	I	4 (4%)
	II	35 (35%)
	III	27 (27%)
	IV	34 (34%)

Source: own calculations

## Quality of life in oncology patients

Tab. 3. Mean and Standard Deviation in the EORTC QLQ-C30 Scale by Gender, Age, and Education of the Study Participants

Skala EORTC QLQ-C30	Overall I	Gender		Age				Education			
		Male	Female	41-50 years	51-60 years	61-70 years	≥71 years	Primary	Secondary	Higher	Vocational
Physical Functioning	58 ±27	65±27	53±27	56±32	63±27	64±27	49±24	30±5	55±26	56±28	62±28
Role Functioning	57± 37	59±38	56±37	63±29	51±39	63±39	50±36	33±47	57±36	63±35	56± 39
Emotional Functioning	83±23	87±20	81±24	73±30	88±14	83±24	84±21	92±12	81±25	86±20	83± 22
Cognitive Functioning	70±31	79±28	65±32	52±37	88±14	70±32	70±29	92±12	69±32	70±34	71± 30
Social Functioning	78±30	79±29	78±31	58±38	81±22	85±26	75±34	83±24	81±28	68±34	80± 31
Global health status/QoL	61±17	61±19	61±16	66±13	58±9	59±20	63±17	75±12	63±16	56±11	61± 20
Fatigue	51±29	46±32	54±27	72±24	45±27	48±29	51±28	56±16	47±26	59±31	51± 30

<b>Nausea/Vomiting</b>	10±21	7±20	11±22	17±27	22±41	8±15	6±13	50±71	7±15	14±24	8± 20
<b>Pain</b>	29±30	21±27	34±30	38±42	19±30	29±29	31±26	8±12	27±25	42±41	28± 28
<b>Dyspnea</b>	10±25	2±11	15±30	3±11	0±0	9±23	17±32	0±0	14±30	6±17	9± 24
<b>Insomnia</b>	43±39	37±38	47±40	47±36	39±34	44±43	43±39	50±71	44±39	33±38	46± 40
<b>Appetite loss</b>	20±34	20±36	20±33	50±42	33±43	17±31	11±26	100±0	14±28	30±38	18± 34
<b>Constipation</b>	20±32	14±32	23±33	23±39	28±45	14±29	23±31	50±71	16±30	26±33	19± 33
<b>Diarrhea</b>	9±23	7±25	10±21	20±36	6±19	9±24	23±31	0±0	7±21	11±23	9± 24
<b>Financial Problems</b>	23±28	16±22	26±30	13±13	11±16	21±27	31±30	33±12	27±23	19±33	20± 28

Source: own calculations

Analysis of the mean values and standard deviations revealed that, among the overall study population, the highest scores were observed in the domains of emotional functioning (83±23) and social functioning (78±30). Conversely, the lowest mean score was recorded in the domain of role functioning (57±37). Among the symptoms most frequently reported by oncology patients were fatigue (51±29) and insomnia (43±39). The mean global quality of life score in the examined group was 61±17 points, indicating a moderate level of overall well-being. Relatively high standard deviations suggest significant variability in quality of life assessments among the study participants.

Among male respondents, the lowest functioning score was recorded for role functioning (59±38), while the highest was in the emotional functioning domain (87±20). Similarly, in the female group, emotional functioning was also the highest-rated dimension (81±24). However, women reported the lowest average score in physical functioning (53±27).

Participants aged 41–50 years demonstrated the lowest average scores in emotional (73±30), cognitive (52±37), and social functioning (58±38) compared to other age groups. Nevertheless, this group achieved the highest mean score in global quality of life (66±13). Physical and role functioning were rated lowest among patients aged 71 and over, 49±24 and 50±36 points, respectively. The highest average scores for emotional and cognitive functioning (88±14) were observed in the 51–60 age group, while social (85±26), physical (64±27), and role functioning (63±39) were highest in patients aged 61–70.

Regardless of sex and age, fatigue emerged as the most prominent symptom among the respondents.

Patients with primary education had the lowest mean scores for physical (30±5) and role functioning (33±47), whereas the highest values for these domains were observed in participants with vocational (62±28) and higher education (63±35). In terms of emotional, cognitive, and social functioning, individuals with primary education achieved the highest average scores—92±12, 92±12, and 83±24 points, respectively. However, higher education was associated with the lowest social functioning score (68±34). Loss of appetite was the most commonly reported symptom among patients with primary education (100±0), distinguishing this group from those with secondary, higher, or vocational education, where fatigue was most frequently reported (Tab. 3).

Tab. 4. Mean and Standard Deviation in the EORTC QLQ-C30 Scale by Place of Residence, Marital Status, and Economic Situation of the Study Participants

Scale EORTC QLQ-C30	Place of residence				Marital Status				Economic situation			
	Village	Town <50,000	City 51,000-200,000	City >200,000	Married	Divorced	Widowed	Single	Very good	Good	Satisfactory	Unsatisfactory
<b>Physical Functioning</b>	65±30	64±24	57±27	49±27	56±26	53±29	61±29	75±32	60±27	57±29	53±22	64±20
<b>Role Functioning</b>	60±32	74±33	52±40	44±39	54±34	64±44	56±41	92±17	59±38	54±38	58±37	72±23
<b>Emotional Functioning</b>	78±20	80±29	77±24	91±17	79±25	84±18	90±18	92±17	83±28	83±21	75±21	97±7
<b>Cognitive Functioning</b>	62±35	74±31	76±27	70±30	69±33	73±31	69±28	83±19	76±33	66±31	71±30	78±27
<b>Social Functioning</b>	81±25	85±25	73±36	74±35	75±30	89±21	78±36	100±0	82±33	76±30	72±34	89±14
<b>Global health status/QoL</b>	55±19	64±19	58±12	64±16	59±17	58±14	66±18	75±15	62±22	60±16	64±13	58±9
<b>Fatigue</b>	49±22	44±32	60±25	54±31	51±28	71±28	45±28	28±28	49±33	54±27	45±22	43±35
<b>Nausea/Vomiting</b>	7±12	9±24	6±15	14±25	12±22	11±19	6±20	0±0	9±21	9±20	15±30	8±20
<b>Pain</b>	25±24	24±28	36±35	34±32	28±30	56±31	25±25	4±8	29±31	31±30	19±21	39±38
<b>Dyspnea</b>	3±14	7±19	10±24	17±34	7±19	6±20	21±37	0±0	14±30	9±24	11±26	0±0
<b>Insomnia</b>	51±36	44±40	33±35	41±43	45±38	36±43	39±40	58±50	43±42	47±38	39±42	17±18
<b>Appetite loss</b>	22±31	21±34	12±31	21±38	23±35	18±35	11±30	33±47	23±36	18±33	31±41	0±0
<b>Constipation</b>	29±37	17±29	19±28	17±34	19±29	33±45	19±36	0±0	9±25	27±36	19±33	11±17
<b>Diarrhea</b>	0±0	13±26	14±31	9±22	8±21	18±35	7±22	0±0	9±23	11±25	0±0	6±14
<b>Financial Problems</b>	23±21	19±31	29±37	23±25	24±29	24±34	19±19	25±15	17±25	18±22	28±24	78±34

Source: own calculations

The average results depending on the place of residence showed that patients living in rural areas were characterized by the poorest cognitive functioning (62±35) and the best physical functioning (65±30) compared to those living in cities. Role and social functioning were rated the highest in the group of people living in towns with up to 50,000 inhabitants (74±33 and 85±25, respectively). Respondents living in cities with 51,000–200,000 inhabitants recorded the highest average scores in cognitive (76±27) and social functioning (73±36), whereas emotional functioning, in comparison to those living in rural areas and cities with up to 50,000 and over 200,000 inhabitants, was rated the lowest in this group (73±36). The lowest average scores for physical functioning (49±27) and role functioning (44±39) were observed among patients living in cities with over 200,000 inhabitants. Emotional functioning among patients residing in cities with more than 200,000 inhabitants showed the highest average values (91±17) compared to the other groups. Results for global quality of life by

place of residence indicated high average values among people living in cities up to 50,000 (64±19) and over 200,000 (64±16). The most common symptom observed among those living in rural areas (51±36) and towns up to 50,000 inhabitants (44±40) was insomnia, while residents of cities with 51,000–200,000 inhabitants (60±25) and over 200,000 (54±31) most frequently reported fatigue.

Married individuals showed the lowest average scores in role functioning (54±34), emotional (79±25), cognitive (69±33), and social functioning (73±30). Physical functioning and global quality of life were rated the lowest among divorced patients (53±29 and 58±14 points, respectively). The highest average scores across all functional scales were observed in patients identifying as single (never married). Fatigue was the most commonly reported symptom among married (51±28), divorced (71±28), and widowed patients (45±28), while insomnia most frequently affected single individuals (58±50).

The highest average results in all functional scales characterized the surveyed group expressing dissatisfaction with their financial situation. The lowest average scores for role and cognitive functioning were observed among individuals reporting a good financial situation (54±38 and 66±31, respectively). A satisfactory economic situation was associated with poorer results in physical (53±22), emotional (75±21), and social functioning (72±34). Regardless of financial situation, the highest average score was recorded for fatigue (Tab. 4).

Tab. 5. Mean and Standard Deviation in the EORTC QLQ-C30 Scale by Clinical Characteristics of the Study Participants

Skala EORTC QLQ-C30	Diagnosis time		Level of advancement				Type of cancer										
	≤12 months	>12 months	I	II	III	IV	Large intestine	Kidney	Bladder	Breast	Lungs	Palate	Prostate	Uterine body	Pancreas	Liver	Stomach
<b>Physical Functioning</b>	56 ± 26	60 ± 29	82 ± 23	54 ± 26	66 ± 25	52 ± 28	59 ± 29	40 ± 0	51 ± 29	73 ± 20	53 ± 25	87 ± 0	87 ± 0	37 ± 24	43 ± 27	49 ± 35	63 ± 25
<b>Role Functioning</b>	58 ± 38	56 ± 36	92 ± 17	54 ± 38	66 ± 33	49 ± 38	65 ± 35	11 ± 19	43 ± 40	80 ± 25	48 ± 36	100 ± 0	100 ± 0	58 ± 59	36 ± 32	44 ± 39	44 ± 38
<b>Emotional Functioning</b>	85 ± 21	79 ± 26	58 ± 17	79 ± 26	90 ± 18	85 ± 21	87 ± 19	94 ± 10	90 ± 22	72 ± 30	72 ± 26	100 ± 0	100 ± 0	83 ± 24	92 ± 13	79 ± 23	81 ± 25
<b>Cognitive Functioning</b>	74 ± 30	63 ± 32	79 ± 16	73 ± 35	75 ± 22	63 ± 33	73 ± 31	22 ± 19	87 ± 14	70 ± 26	72 ± 28	100 ± 0	100 ± 0	67 ± 47	56 ± 27	50 ± 41	77 ± 30
<b>Social Functioning</b>	78 ± 29	79 ± 33	96 ± 8	71 ± 33	85 ± 21	79 ± 34	81 ± 31	33 ± 58	80 ± 30	88 ± 21	85 ± 20	100 ± 0	67 ± 0	83 ± 24	50 ± 33	100 ± 0	68 ± 30
<b>Global health status/QoL</b>	62 ± 18	60 ± 17	67 ± 14	59 ± 18	67 ± 15	58 ± 18	64 ± 17	47 ± 5	67 ± 12	61 ± 10	58 ± 12	50 ± 0	58 ± 0	46 ± 6	58 ± 20	58 ± 7	60 ± 28
<b>Fatigue</b>	49 ± 28	55 ± 31	39 ± 26	44 ± 29	51 ± 26	60 ± 30	49 ± 29	70 ± 13	51 ± 39	46 ± 27	52 ± 26	67 ± 0	11 ± 0	72 ± 8	63 ± 29	56 ± 23	44 ± 36

<b>Nausea/Vomiting</b>	10 ± 23	9 ± 18	21 ± 32	13 ± 27	6 ± 14	8 ± 17	11 ± 20	0 ± 0	0 ± 0	0 ± 0	25 ± 41	0 ± 0	0 ± 0	0 ± 0	8 ± 20	0 ± 0	10 ± 14
<b>Pain</b>	29 ± 28	30 ± 34	25 ± 29	28 ± 24	25 ± 28	36 ± 36	32 ± 32	44 ± 10	30 ± 41	18 ± 25	17 ± 21	50 ± 0	0 ± 0	42 ± 12	44 ± 39	28 ± 39	28 ± 23
<b>Dyspnea</b>	3 ± 13	25 ± 37	8 ± 17	3 ± 12	12 ± 26	16 ± 33	13 ± 28	0 ± 0	0 ± 0	0 ± 0	30 ± 40	67 ± 0	0 ± 0	33 ± 47	0 ± 0	0 ± 0	0 ± 0
<b>Insomnia</b>	42 ± 39	45 ± 41	42 ± 42	42 ± 36	41 ± 35	46 ± 46	46 ± 39	67 ± 58	53 ± 45	37 ± 37	50 ± 48	0 ± 0	0 ± 0	33 ± 47	17 ± 18	67 ± 37	28 ± 30
<b>Appetite loss</b>	20 ± 34	20 ± 36	25 ± 32	25 ± 36	20 ± 32	15 ± 34	17 ± 34	0 ± 0	47 ± 45	17 ± 28	33 ± 42	0 ± 0	0 ± 0	33 ± 47	0 ± 0	0 ± 0	31 ± 40
<b>Constipation</b>	21 ± 33	18 ± 33	33 ± 38	22 ± 31	20 ± 32	17 ± 34	13 ± 26	44 ± 38	13 ± 30	13 ± 28	43 ± 45	0 ± 0	0 ± 0	66 ± 47	28 ± 33	33 ± 42	10 ± 25
<b>Diarrhea</b>	7 ± 21	11 ± 25	17 ± 33	6 ± 19	12 ± 25	8 ± 23	12 ± 26	0 ± 0	0 ± 0	0 ± 0	3 ± 11	0 ± 0	0 ± 0	0 ± 0	6 ± 14	11 ± 27	13 ± 29
<b>Financial Problems</b>	27 ± 30	14 ± 20	8 ± 17	30 ± 28	20 ± 27	19 ± 27	27 ± 31	22 ± 19	13 ± 18	27 ± 41	13 ± 23	33 ± 0	33 ± 33	17 ± 24	28 ± 14	11 ± 17	21 ± 26

Source: own calculations

The analysis of quality-of-life parameters in relation to the duration of cancer revealed significant differences between groups. Higher average scores for role functioning ( $58 \pm 38$ ), emotional functioning ( $85 \pm 21$ ), cognitive functioning ( $74 \pm 30$ ), and global quality of life ( $62 \pm 18$ ) were observed among individuals diagnosed  $\leq 12$  months prior. Patients with a longer time since diagnosis were characterized by higher average scores in the domains of physical functioning ( $60 \pm 29$ ) and social functioning ( $79 \pm 33$ ). In the context of symptoms, it was observed that with increasing disease duration, the risk of nearly all symptoms increased, with the exception of nausea and vomiting, as well as loss of appetite.

The first stage of cancer was associated with the highest average scores in physical functioning ( $82 \pm 23$ ), role functioning ( $92 \pm 17$ ), cognitive functioning ( $79 \pm 16$ ), and social functioning ( $96 \pm 8$ ). However, the highest emotional functioning was observed among patients with stage III cancer ( $90 \pm 18$ ). The lowest score for global quality of life was recorded among respondents with stage II cancer ( $59 \pm 18$ ). Patients with stage IV cancer were characterized by the lowest average scores in physical functioning ( $52 \pm 28$ ), role functioning ( $49 \pm 38$ ), and cognitive functioning ( $63 \pm 33$ ). Fatigue was most frequently reported among respondents with stage II, III, and IV cancer, while insomnia was the most common symptom among patients with stage I cancer.

The lowest average scores for physical functioning ( $40 \pm 0$ ), role functioning ( $11 \pm 19$ ), cognitive functioning ( $22 \pm 19$ ), and social functioning ( $33 \pm 58$ ) were recorded among patients with kidney cancer. Emotional functioning was the lowest-rated domain among patients with breast cancer ( $72 \pm 30$ ) and lung cancer ( $72 \pm 26$ ). The lowest global quality of life score was found among patients with endometrial cancer ( $46 \pm 6$ ). Insomnia was the most frequently reported symptom among patients with bladder cancer ( $53 \pm 45$ ) and liver cancer ( $67 \pm 37$ ), in contrast to other cancer types, where fatigue predominated (Tab. 5).

## Discussion

The study we conducted, which describes disease-related quality of life among patients undergoing chemotherapy, constitutes a significant contribution to the ongoing analyses addressing various dimensions of functioning and symptom burden during oncological treatment.

Our findings demonstrated that, among the general population of cancer patients undergoing chemotherapy, the mean score for global health status/quality of life was  $61 \pm 17$  points. Similar observations were presented by Machingura et al. in a comprehensive retrospective study utilizing existing databases, including those from EORTC and the Canadian Cancer Trials Group. According to the results cited in that study, the mean global health status/quality of life among the general cancer population was  $65 \pm 23$  points [5]. A cross-sectional hospital-based study by Ebob-Any and Bassah involving 120 cancer patients reported a mean global health status/quality of life score of  $52 \pm 21.3$  [14]. Global quality of life was also evaluated in the study by Bozcuk et al., who assessed 97 patients admitted to the chemotherapy department at the Faculty of Medicine, Akdeniz University in Antalya. The authors reported that, among the 32 patients not participating in any additional interventions, the mean global quality of life score was  $60.8 \pm 19.9$  points [15]. In our own study, global quality of life and health status were also presented in relation to cancer stage (Stage I –  $67 \pm 14$ , Stage II –  $59 \pm 18$ , Stage III –  $67 \pm 15$ , and Stage IV –  $58 \pm 18$ ). Slightly higher values regarding global quality of life/health status were reported in the review by Chung et al., describing quality of life based on cancer stage among patients with cervical cancer. According to the presented data, global quality of life/health status in early-stage cancer was  $76.1 \pm 2.2$ , while in advanced-stage cancer it was  $72.9 \pm 1.7$  [16].

Such a substantial difference may be attributed to the inclusion, in our study, of patients with various types of cancer, which directly correlates with diverse disease courses and associated limitations. Physical, role, emotional, cognitive, and social functioning in the context of quality of life is discussed in the work of Kállay et al. The authors, in their publication encompassing a sample of 330 cancer patients with various cancer types, observed the highest mean score in cognitive functioning ( $73.15 \pm 26.60$ ) and the lowest in physical functioning ( $66.10 \pm 21.44$ ) [17]. Machingura et al., referring to physical ( $79 \pm 21$ ), role ( $72 \pm 31$ ), emotional ( $73 \pm 22$ ), cognitive ( $83 \pm 20$ ), and social ( $76 \pm 28$ ) functioning, indicate generally good performance across all domains of quality of life, with a particularly high score in the cognitive domain [5]. Ebob-Any and Bassah also reported the highest score in cognitive functioning ( $78.9 \pm 23.0$ ) in their study. Furthermore, the authors emphasized that role functioning was the lowest-rated quality of life dimension ( $59.6 \pm 37.9$ ) [14]. Mattei et al., who assessed the quality of life in a group of 105 women with gynecological cancers undergoing chemotherapy, reported three domains with equally high scores—role, cognitive, and social functioning (Me=100). In the aforementioned study, the authors indicated emotional functioning as the most poorly rated aspect of life (Me = 83.33) [18]. The results presented by these authors regarding the highest-rated aspect of quality of life differ from our findings, which indicated emotional functioning as the most positively assessed dimension ( $83 \pm 23$ ). Additionally, our data point to role functioning as the lowest-rated domain ( $57 \pm 37$ ), which partially aligns with the results presented in other studies. A comparison of the EORTC QLQ-C30 and EORTC QLQ-LC13 questionnaires conducted by Szop et al. provided findings related to physical functioning in 483 patients with non-small cell lung cancer. The study outcomes were reported for two time points:

baseline and seven weeks post-initial assessment, showing physical functioning scores of  $77.8 \pm 18.4$  and  $74.9 \pm 20.4$  points, respectively. In relation to our own findings for patients with lung cancer, a significant discrepancy in physical functioning scores was noted in this subgroup ( $53 \pm 25$ ) [19].

The most frequently reported symptoms among our sample of patients undergoing chemotherapy were fatigue ( $51 \pm 29$ ), insomnia ( $43 \pm 39$ ), and pain ( $29 \pm 30$ ). Lewandowska et al., examining quality of life in 800 cancer patients receiving chemotherapy using the ESAS scale, demonstrated that the most commonly reported complaints included fatigue, constipation, loss of appetite, pain, and sleep disturbances [11]. Similarly, Machingura et al. listed fatigue ( $33 \pm 26$ ), insomnia ( $29 \pm 31$ ), and pain ( $26 \pm 28$ ) as the most frequently reported symptoms [5].

In the study conducted by Choueiri et al. involving 994 patients with renal cell carcinoma including both an intervention and control group, the authors observed mean scores for global health status/quality of life of  $79.2 \pm 18.5$  in the intervention group and  $77 \pm 17.6$  in the control group. Regarding physical functioning, the study reported mean scores of  $88.6 \pm 15$  in the intervention group and  $88.6 \pm 14.3$  in the control group [20]. Referring to our results, patients with kidney cancer demonstrated mean scores for global health status/quality of life and physical functioning of  $47 \pm 5$  and  $40 \pm 5$ , respectively, indicating relatively low quality of life and health status, as well as notable limitations in physical functioning.

Quality of life and its dimensions among patients with metastatic pancreatic cancer were described by Amin et al., who reported a mean global health status/quality of life score of 54.3, role functioning of 62.5, cognitive functioning of 81.5, and physical functioning of 78.2. Symptom assessment revealed significant issues related to fatigue (46.0) and pain (41.9) [21]. These results partially overlap with the outcomes of our study. The most frequently reported symptoms among our participants were fatigue ( $63 \pm 29$ ) and pain ( $44 \pm 39$ ). The mean global health status/quality of life score also showed similar values ( $58 \pm 20$ ); however, the mean scores for physical, cognitive, and role functioning were  $43 \pm 27$ ,  $56 \pm 27$ , and  $36 \pm 32$ , respectively. These differences may result from the smaller sample size of patients with pancreatic cancer included in our study.

Our study provides valuable insights into the quality of life among cancer patients undergoing chemotherapy, addressing both overall health status/quality of life and specific dimensions of functioning, as well as the symptoms experienced throughout the course of the disease. The results presented in relation to global health status/quality of life and reported symptoms are generally consistent with those reported by other authors. However, attention should be drawn to the differences observed in relation to cancer stage, cancer type, and specific functional domains. Nonetheless, our study has certain limitations stemming from a relatively small research sample that included patients with various cancer types, which restricts the generalizability of the results to the broader population. Furthermore, it is important to consider the use of a self-report tool, which carries the risk of receiving distorted outcomes influenced by participants' subjective perceptions and personal beliefs. Future research should focus on a more detailed examination of these aspects and involve a larger sample size to allow for more specific conclusions regarding patient needs, identifying high-risk groups requiring supportive interventions aimed at improving quality of life during oncological treatment.

## Conclusions

The aim of the conducted study was to assess the quality of life of oncology patients receiving chemotherapy, taking into account selected individual, economic, and clinical factors. The quality of life of the surveyed patients varied across different dimensions of functioning. The greatest limitations were observed in physical functioning, role functioning, and global health status/quality of life. The most frequently reported symptoms were fatigue, insomnia, and pain. A variation in results was observed depending on individual characteristics, economic situation, and clinical conditions. The results suggest that higher scores in specific functioning domains were obtained by men, individuals declaring satisfaction with their economic situation, and patients with a shorter time since diagnosis. Global health status/quality of life was more favorably assessed by patients with primary education, living in urban areas, being single, with a shorter time since diagnosis, and declaring a satisfactory economic situation. Insomnia was the most frequently reported symptom among patients living in rural areas, single individuals, and patients with liver or bladder cancer as well as with stage I of disease advancement.

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# GREEN HEALING PROGRAM AS A SUPPORTIVE PARTNER IN PATIENT RECOVERY

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## Abstract:

The article presents results of the evaluation of the “Green Healing” program, launched by the Municipal Greenery Board in Poznań to support patient recovery through direct contact with nature. A survey of 100 participants in lectures and workshops showed that most rated the program positively, noting benefits for knowledge, mental and physical well-being, and willingness to rejoin. The initiative was seen as a valuable complement to hospital treatment, especially by frequently hospitalised patients. Respondents praised the organisation, relevance of topics, and accessibility of content, with the majority willing to recommend it to others. The results align with global trends and confirm the effectiveness of nature-based interventions in enhancing well-being and supporting recovery.

## Keywords:

*Green Healing; contact with nature; patient well-being; environmental therapy*

## Introduction

In today’s world, society is more than ever exposed to the challenges associated with rapid urbanization and development. The increasing level of stress, which negatively impacts health, prompts the search for new, unconventional therapeutic methods. Green Care is an evidence-based approach that uses nature and the outdoors to enhance physical, mental, and emotional well-being. It is a structured therapeutic intervention where nature actively participates in the healing process. The Green Care Quality Manual (Luke and THL, 2017) addresses nature safety issues, such as avoiding poisonous plants and ensuring everyone’s rights and responsibilities, especially in relation to freedom of movement [1]. Green Care methods not only support physical and mental health but also strengthen social bonds and a sense of agency [2]. Numerous studies indicate that contact with nature is a valuable complement to traditional therapies, enhancing patients’ quality of life. In the face of contemporary challenges, programs such as Green Healing are gaining importance and may serve as a model for the implementation of similar initiatives in healthcare and education.

The “Green Healing” program, implemented by the Poznan City Greenery Authority, aims to make nature a partner in the process of patient recovery. The project integrates modern medical

approaches with elements of urban nature to provide hospital patients and workshop participants with opportunities to improve both their physical and mental health through direct contact with nature. The program includes lectures and workshops, which are available to all individuals, regardless of gender, age, or socio-economic background [3]. A survey was coordinated by the Poznan City Greenery Authority and conducted among 100 participants who attended the lectures, to gather their opinions on the events organized by the Poznan City Greenery Authority as a part of the Green Healing program.

The following assumptions were made when analysing the survey results:

Likert scale responses were assigned the following codes:

- Definitely yes +2
- Rather yes +1
- I have no opinion 0
- Rather not -1
- Definitely not -2

In the absence of a marked answer, the answer “I have no opinion” with a code equal to ‘0’ was admitted. In cases where respondents gave two answers at the same time and did not cross out neither of them, the one with the higher code was selected.

## **Overall respondent statistics**

The study involved 100 individuals participating in events under the Green Healing program. Among the respondents, there were 52 women (52%) and 46 men (46%), while 2 individuals (2%) did not specify their gender. The gender distribution indicates a slight predominance of women among participants, which may suggest a greater interest in health and environmental topics or a higher willingness among women to engage in health-promoting activities.

Employment was declared by 53% of participants, meaning that more than half of the respondents are professionally active. Individuals receiving retirement or disability benefits made up 22% of the total, indicating that a significant portion of participants are older adults or unable to work. The non-working group represented 16% of respondents, showing that individuals not engaged in the labour market were also present, although to a lesser extent. The smallest category was students, whose participation in the program was marginal. This may indicate limited interest in the program among young people or students, or possibly a mismatch between the format of the events and the needs of this age group. However, it is important to note that the low representation of certain categories, such as students, may limit the ability to draw general conclusions and may affect the reliability of results related to these groups.

Hospitalization frequency varied notably among the respondents. A total of 8% reported being hospitalized very rarely, while 24% indicated rare hospital stays. The largest group, comprising 40% of participants, reported being hospitalized frequently, and an additional 28% stated that they had been hospitalized very frequently. These findings suggest that a significant proportion of the surveyed individuals have regular contact with the healthcare system, potentially due to chronic health conditions or age-related issues. Nonetheless, the small proportion of individuals who reported very

rare use of healthcare services may have significantly influenced the results for this category if a larger number of respondents had been represented in it.

## To what extent participation in the event influenced attendees?

First part of the survey covered questions about the impact of the lecture on their attendees. There were seven questions connected with the influence on their well-being, possible usage of the knowledge gained and other circumstances. Generally, the influence was perceived positively with the majority of the responses for all of the seven questions between 2 and 1. Which stand for “definitely yes” and “rather yes”. Fig. 1 presents the general distribution of "rather yes" and higher responses to the analyzed questions.

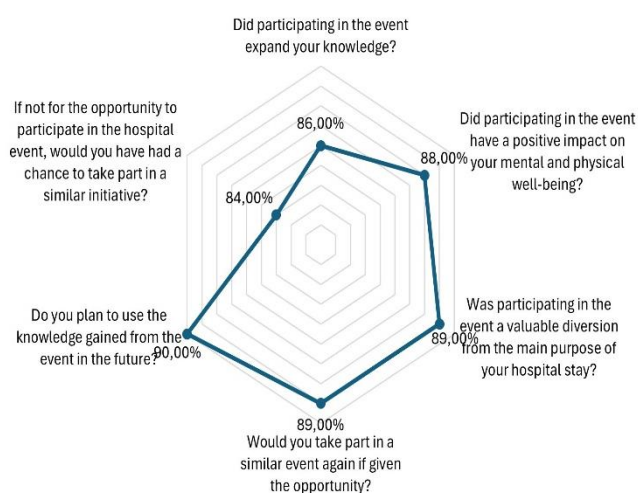


Fig. 1. Distribution of "rather yes" and higher responses to the analyzed questions concerning the impact of the “Green Healing” program on all respondents

Source: data based on the survey’s results conducted by the City Greenery Authority in Poznań

### Does it widen their knowledge?

The respondents were asked a question “Does the lecture widen your knowledge?”. The majority of the responses, which was exactly 70% of them, the attendees said that it “definitely” broadened their knowledge. There were no negative responses such as “rather not” or “definitely not”. Difference between men and women answering this question was slightly different, with only 9 more women saying that the lecture definitely widened their knowledge.

However, there was a very visible difference in responses from people in terms of “professional activity”. 42 of the responses that the lecture definitely widened their knowledge was from people who are professionally active, whereas only 6 of the people who are currently studying said that it definitely widened their knowledge.

Among individuals who were hospitalized "very frequently," as many as 78.6% declared that the program significantly enhanced their knowledge. In the group who were hospitalized "frequently," this percentage was 67.5%. Even among those who visited the hospital "rarely" or "very rarely," the majority reported an increase in knowledge: 83.3% answered "definitely yes," and 75% answered "rather yes". These results clearly indicate that the "Green Treatment" program was perceived by participants as effective in expanding their knowledge, regardless of the frequency of hospital visits.

The highest number of positive responses came from respondents who had more frequent contact with medical facilities, suggesting that individuals more engaged in the treatment process are also more aware of the value of educational programs. The absence of negative responses, such as "rather no" or "definitely no," further indicates a positive reception of the program.

### **How did it influence their psychological and physical well-being?**

The respondents also were given a question about their well - being. They were separately asked about their physical and psychological state. In both cases the mode was "definitely yes". In both this answer passed the 50% of the responses. However in terms of physical well - being, 13% of the responses were "I have no opinion", while in psychological well - being it was only 9% of the responses. In both cases more women answered "definitely yes" than men.

Again, the majority of people professionally active stated that the lecture had a positive impact on them in both physical and psychological well - being. 57% of the answers were "definitely yes", this states that regardless of the professional activity, for more than a half of the participants the programme had a positive impact on their well-being. Also, more than a half of "professionally active" participants answered, "definitely yes". That was 56% of their responses. On the other hand, among "professionally inactive" respondents 63% of them also responded "definitely yes". This provides a general conclusion that regardless of the profession, the influence on psychological and physical well-being was received positively.

Across all hospitalization frequency groups, respondents reported a generally positive impact of the program on both mental and physical well-being. Among those hospitalized very frequently, 60.71% noticed a significant improvement in their mental state, and 28.57% assessed their condition as "rather yes". Similarly, 60% of frequently hospitalized participants reported a strong mental benefit, with another 30% responding "rather yes". Rarely and very rarely hospitalized individuals also showed favourable responses: over 90% in the "rarely" group and 87.5% in the "very rarely" group selected "definitely yes" or "rather yes. Only one person in the latter group expressed doubt about the mental benefits. These findings suggest that those more engaged in hospital care, may be more open to psychological and educational interventions.

Physical well-being showed a comparable trend, though slightly less pronounced. In the frequently hospitalized group, 68% reported significant improvement, while 18% were undecided and 10% did not notice a benefit. Among very frequently hospitalized individuals, 54% noticed a significant improvement and 39% answered "rather yes", with no respondents selecting a negative answer. In the rarely and very rarely hospitalized groups, 50–54% declared definite improvement and 38% responded "rather yes". Overall, the data suggest the program positively influenced physical and mental well-being, particularly among those with more frequent hospital stays.

### **Was it a valuable treat from the main purpose of the stay?**

The lecture was not the main purpose of the stay and that is why the attendees were asked a question whether it was valuable or not. Based on Fig. 1, 61% of the respondents answered, "definitely yes" and 28% answered "rather yes" which indicates that the lecture might have been beneficial for them. Nonetheless, 11% of the respondents said that they "have no opinion", which was given by the majority of the men. On the other hand, the answer "definitely yes" was equal in terms of gender.

In this case also people who are “currently studying” responded only “definitely yes” and “rather yes”. Based on the professional activity 61% of the answers was “definitely yes” and in each category individually, 50% or more of the answers also were “definitely yes”. Hence, the lecture was generally valuable for the majority of the participants. The answer “rather yes” was chosen by the 28% of the respondents, which in summary gives 89% of the positive answers amid participants.

The "Green Treatment" program was positively received by a majority of participants across all hospitalization groups. Over 50% in each group answered "definitely yes" when asked about its impact on their well-being. The highest levels of enthusiasm came from the "frequently" and "very frequently" hospitalized groups, with 65% and 64% respectively selecting "definitely yes". Those hospitalized "rarely" and "very rarely" also viewed the program favourably, though 54% and slightly less than 50% responded positively. A higher frequency of "No opinion" responses was observed among the less hospitalized, suggesting a less pronounced impact in that group. Importantly, no respondent rated the program negatively, confirming its strong effectiveness and positive reception. Overall, the program serves as a meaningful diversion, particularly for those with frequent hospital stays.

### **Will they participate again?**

The participants were also asked a question whether they will take part in the lecture again. As presented in Fig. 1, 89% of the responses were positive, where 65% of them were “definitely yes” and 24% “rather yes”. Only two people said that they “rather not” participate in the event again. Among gender the responses were similar. 33 men said that they will participate again and this was only 3 more than in women responses.

Based on the professional activity 61% of the answers was “definitely yes” and in each category individually, 50% or more of the answers also were “definitely yes”. Hence, the lecture was generally valuable for the majority of the participants. The answer “rather yes” was chosen by the 28% of the respondents, which in summary gives 89% of the positive answers within participants.

Among those who stay in the hospital "very often," as many as 71.4% (20 out of 28) declared that they would definitely use the program again. Among those who "often" visit the hospital, this percentage is 72.5% (29 out of 40). Individuals who stay in the hospital "rarely" or "very rarely" also expressed a willingness to use the program again. In these groups, the percentages were 50% (12 out of 24) and 50% (4 out of 8), respectively. The results clearly indicate that the "Green Healing" program is well received by hospital patients. Regardless of the frequency of hospital visits, most respondents showed a strong willingness to use the program again. The lack of "definitely not" responses highlights the effectiveness of the project.

### **Will they use their knowledge in the future?**

Another question covered possible future usage of the knowledge gained during the lecture. As shown in Fig. 1, 90% of the respondents responded either “definitely yes” or “rather yes”. This means that the lecture was useful and insightful for the majority of the attendees. However, there were two responses for “rather not” and they were answered by both man and woman.

In terms of professional activity, the knowledge gained during the program would be “definitely” useful for 68% of “professionally active” respondents. In other categories the percentage of people who ‘definitely’ use their knowledge after the lecture is above 50% of the answers.

Among respondents who indicated "very frequent" hospital stays, 71.4% (20 out of 28) stated that they would definitely apply the knowledge gained through the program. Among those who stay in the hospital "often", this figure was 67.5% (27 out of 40). In the groups who marked their hospital visits as "rare" and "very rare", the percentages were 54.1% (13 out of 24) and 37.5% (3 out of 8), respectively. These findings suggest that the content delivered during the program effectively reaches its audience regardless of how often they are hospitalized. The lower percentages in the "rare" and "very rare" groups may indicate lower interest in educational programs used in the treatment process.

### **Would they participate, if it wasn't due to the hospital?**

Last question asked in this section of the survey was "if you weren't in the hospital, would you still participate in a similar event?". According to Fig. 1, 61% of the respondents said, "definitely yes" and 23% "rather yes" which shows that the stay in the hospital did not influence their choice to participate in the lecture. Nevertheless, one person said that they would definitely not participate in such an event in other circumstances.

In this case, the responses "definitely yes" were slightly more frequent from men than women and more women said that they have no opinion. In terms of professional activity, the answers "definitely yes" and "rather yes" were also equally high chosen in every category.

Similarly to previous answers, based on the professional activity, 50% or more responses were "definitely yes". 70% of the participants who are professionally active answered "definitely yes". However, 15% of the answers were "I have no opinion", though this does not indicate negative impact of the program on the respondents. Among the patients who participated in the survey, 64.2% (18 out of 28) of those hospitalized very frequently stated that they would have the opportunity to take part in a similar event. In the group of patients who "often" visit medical facilities, the percentage was 67.5% (27 out of 40). Among those who selected "rarely," one person indicated a definite lack of opportunity to participate in such a project. Nevertheless, the percentage in this group still reached 54.1% (13 out of 24). In the "very rarely" group, 37.5% (3 out of 8) responded positively. Analysis of the responses shows that programs similar to "Green Healing" are becoming increasingly popular and accessible. The higher percentages among patients who spend more time in hospitals may indicate a greater interest in such initiatives and a willingness to expand their knowledge through program content.

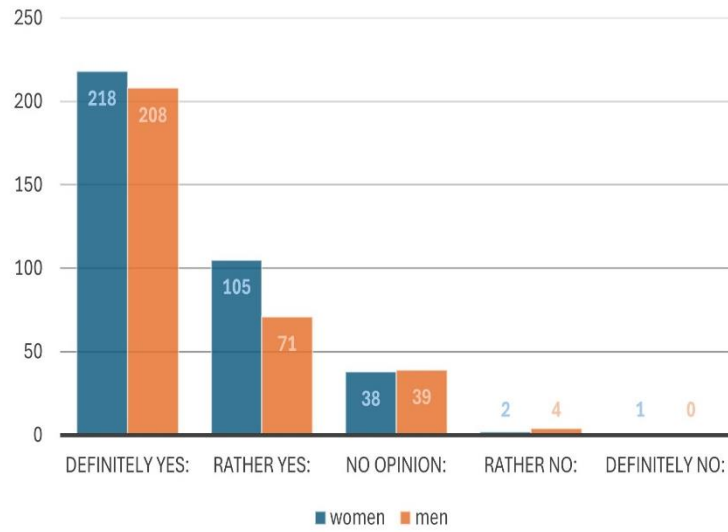


Fig. 2. Gender-based distribution of responses to the analyzed questions regarding the impact of the "Green Healing" program on respondents  
Source: data based on the survey's results conducted by the City Greenery Authority in Poznań

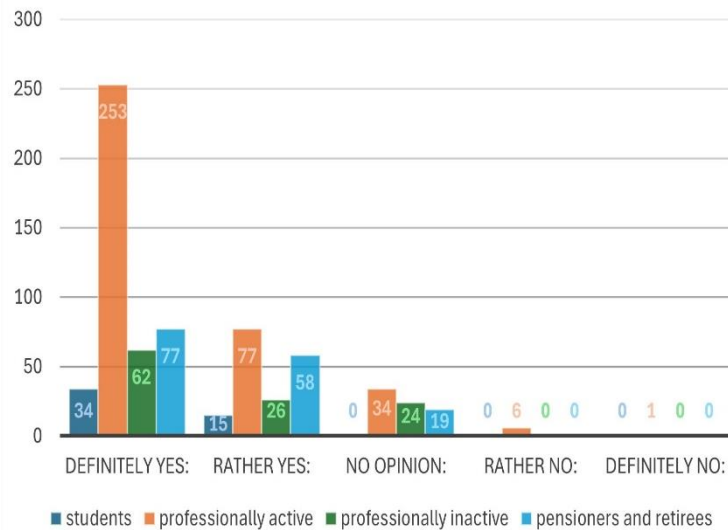


Fig. 3. Distribution of responses by employment status to the analyzed questions regarding the impact of the "Green Healing" program on respondents  
Source: data from the surveys conducted by the City Greenery Authority in Poznań

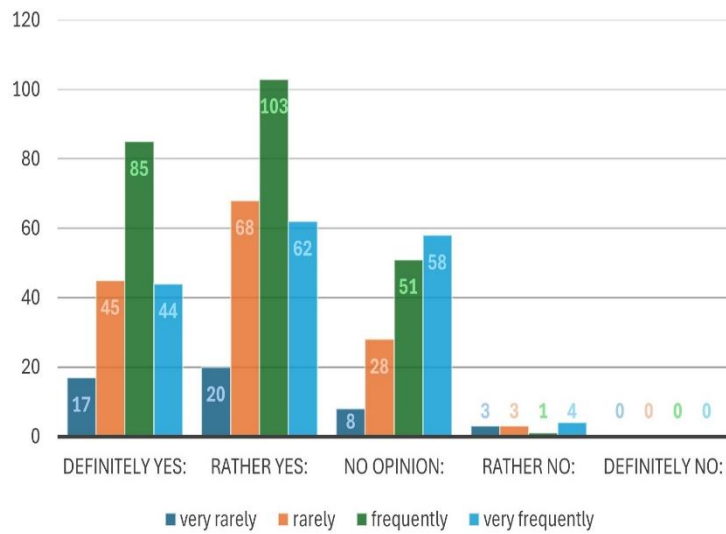


Fig. 4. Distribution of responses by frequency of hospital stays to the analyzed questions regarding the impact of the "Green Healing" program on respondents  
Source: data from the surveys conducted by the City Greenery Authority in Poznań

## Evaluation of the "Green Healing" program's organization

Respondents were asked to share their opinions using a 5-point Likert scale regarding the execution and structure of the "Green Healing" initiative. They were requested to express their views on the program's duration and venue, as well as the appeal of its format and subject matter. Additionally, participants were queried about how clearly the content was communicated and whether they would recommend the program to others. Fig. 5 presents the general distribution of "rather yes" and higher responses to the analyzed questions.

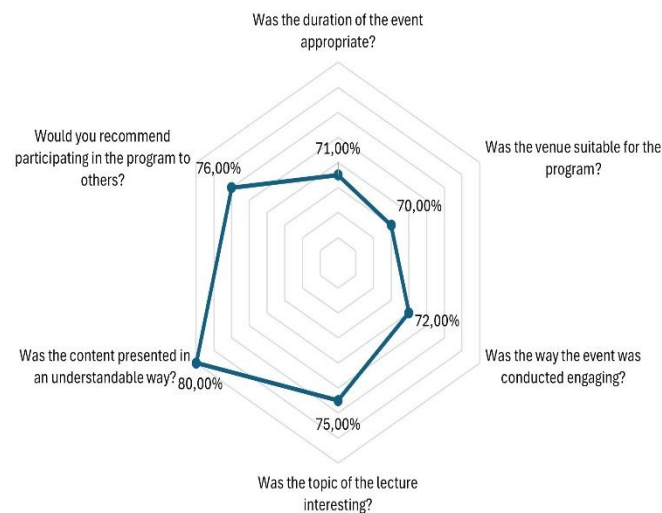


Fig. 5. Distribution of "rather yes" and higher responses to the analyzed questions concerning the evaluation of the "Green Healing" program's organization by all respondents  
Source: data based on the survey's results conducted by the City Greenery Authority in Poznań

### **Was the duration of the "Green Healing" program appropriate?**

As presented in Fig. 5, 71% of participants deemed the length of the program at least satisfactory — responding with “rather yes.”

When broken down by gender, 82.7% of women rated the event’s duration as at least suitable — “rather yes” — with 38.5% of them indicating it was highly appropriate — “definitely yes.” A majority of male respondents also considered the time span to be reasonably fitting — “rather yes”; however, only 21.7% of this group rated it as very suitable — “definitely yes.” Notably, three times more men than women were undecided — answering “no opinion” — comprising 24% of total responses from both demographics. Two individuals who did not identify their gender responded with “rather yes” and “no opinion,” respectively.

The responses were also analysed based on participants’ professional engagement. Among those “currently in education,” all found the program’s length to be at least adequate — with 57.1% describing it as extremely appropriate — “definitely yes.” In the “employed” group, 81.1% rated the time frame as satisfactory — “rather yes.” Conversely, a significant portion of “non-working” respondents remained neutral — “no opinion” — accounting for 56.3% of this segment, which was the highest rate of indecisiveness among all subgroups. The remainder of the non-employed participants evaluated the duration as at least acceptable — “rather yes.” Within the “retirees and pensioners” category, 59.1% viewed the duration favourably — “rather yes.”

The frequency of hospitalization among respondents also influenced the assessment of the duration of the "Green Healing" lecture. Among those who were hospitalized either very rarely or rarely, as many as 75% were at least satisfied—answering “rather yes”—with the length of the program. A similar level of satisfaction was observed among those hospitalized frequently. In contrast, among individuals who were hospitalized very frequently, only just under 61% shared this positive opinion, while the remaining 11 people in this group did not express an opinion. Across all respondents, 4 people expressed dissatisfaction—answering “rather no.”

### **Was the venue of the "Green Healing" program suitable?**

According to Fig. 5, 70% of those surveyed assessed the event’s location as at least satisfactory — “rather yes.”

A majority of both female and male respondents agreed that the venue was reasonably appropriate — “rather yes” — making up 68% of total responses. It is worth noting that 28% of participants did not express a definitive opinion. Both individuals who did not disclose their gender agreed that the location was suitable — “rather yes.”

Among various occupational categories, the highest level of satisfaction with the venue was observed among individuals “currently in education” — with 85.7% rating the location as at least appropriate — “rather yes.” Next in line were the “employed” respondents, where over 73% found the venue at least satisfactory. It is important to note, however, that students comprised only 7% of the total sample, meaning the limited number of responses may not be fully representative of a larger student population. In contrast, the “employed” group made up 53% of all participants, offering a more severe data set. Meanwhile, more than 68% of “retirees and pensioners” expressed satisfaction with the program's location.

In the case of those who are hospitalized rarely or very rarely, the assessment of the event venue indicated at least an adequate location—“rather yes”—in 75% of responses. Identical opinions were given by those who are hospitalized frequently. However, among respondents who are hospitalized very frequently, slightly more than 57% were at least satisfied with the location of the "Green Healing" program. The remaining 12 individuals in this group gave a neutral response—“no opinion.”

### **Was the method of delivering the "Green Healing" session engaging?**

According to the data presented in Fig. 5, 72% of respondents felt that the manner in which the program was conducted was at least engaging — “rather yes.”

Among women, more than 80% found the presentation style to be at least somewhat appealing — “rather yes.” Similarly, the majority of men shared this sentiment, although the figure was slightly lower, at just under 61%. Additionally, 27% of all participants remained neutral, selecting “no opinion.” Both individuals who did not disclose their gender also evaluated the delivery method as at least engaging — “rather yes”.

When segmented by occupational status, all individuals “currently studying” indicated that the method of delivery was at least satisfactory — “rather yes” — with 71% rating it as very engaging — “definitely yes.” In the “employed” category, 70% expressed positive feedback. For “non-working” participants, the satisfaction rate was lower, with fewer than 57% finding the presentation style appealing. The lowest satisfaction came from the “retirees and pensioners” group, where only 54.5% considered the program format better than average. In this section as well, 27% of total respondents chose not to state a clear opinion.

This time, the evaluations according to the frequency of hospitalization differed slightly. The lecture delivery style turned out to be the most attractive to individuals who are frequently hospitalized. As many as 80% of them stated that the presenters conducted the session in at least an interesting way—“rather yes.” A similar opinion was expressed by the majority of the remaining respondent groups. Among those hospitalized very rarely and rarely, the respective satisfaction levels were 75% and just under 71%, while among those hospitalized very frequently, just under 61% were satisfied. Across all respondents, as many as 27% did not express an opinion.

### **Was the content of the "Green Healing" program interesting?**

As shown in Fig. 5, 75% of the surveyed individuals rated the program’s topics as interesting or very engaging.

Nearly 85% of women were at least intrigued by the subject matter — “rather yes”, while this sentiment was shared by 63% of men. Overall, nearly one-third of participants found the theme highly compelling — “definitely yes”, with women forming the majority in this category. The two individuals who did not specify their gender also showed interest.

Every respondent classified as “in education” agreed that the topics discussed were at least somewhat compelling — “rather yes.” In the “working professionals” group, almost 83% expressed similar views. Among “non-employed” individuals, half showed interest in the content — “rather yes.” In the “retirees and pensioners” segment, just over 63% responded positively. A total of 24% of participants did not express an opinion on the thematic relevance.

In terms of “interesting subject area” the highest number of participants who chose “definitely yes” were those who visit the hospital “often”. However, the respondents generally said that it was

“rather interesting”. One response was even “rather not”, though it is not that significant. The majority of participants who visit the hospital “very often” answered that they have no opinion, nonetheless it is only 35% of all the answers. On the other hand, among the participants who visit the hospital “very rarely” they answered that the lecture was “rather” interesting the most.

### **Was the information presented during the "Green Healing" program clear and understandable?**

Based on Fig. 5, 80% of respondents stated they understood the content reasonably well — “rather yes.”

A majority of both women and men confirmed that the material was at least clear — “rather understandable.” For women, this accounted for over 84% of responses; for men, just under 74%. Across all participants, more than one-third considered the knowledge conveyed to be highly accessible — “definitely yes.”

All individuals “currently in school” assessed the content as at least comprehensible — “rather yes.” A similar opinion was held by nearly 85% of the largest group, the “employed.” Among “retirees and pensioners,” the rate was just under 73%, while for the “non-working” group it reached 62.5%. The undecided respondents accounted for 19% of the total sample.

In the matter of understandable content of the program 45% of all answers were “rather yes”. Though this is not even half of the responses, 35% of the participants responded, “definitely yes” and in summary this indicates positive reception of the content. Respectively 16 and 17 answers “definitely yes” and “rather yes” were from people who visit hospital “often”. Again, there was one response “rather not” and it was from a person who visits the hospital “very often”.

### **Would you recommend the "Green Healing" program to others?**

The results displayed in Fig. 5 show that 76% of participants would suggest the program to others.

Among those likely to endorse the initiative — “rather yes” — more than 80% were women, and nearly 70% were men. Approximately one-third of respondents stated they would strongly recommend it — “definitely yes.”

When responses were analysed by occupational status, over 85% of participants “currently studying” said they would likely recommend attending the program. Similarly, 77% of “employed” respondents shared this view. In the “non-working” group, 62.5% would also suggest participation. Within the “retirees and pensioners” category, 17 individuals, making up over 77% of this group, responded that they would likely advocate for others to join the "Green Healing" session.

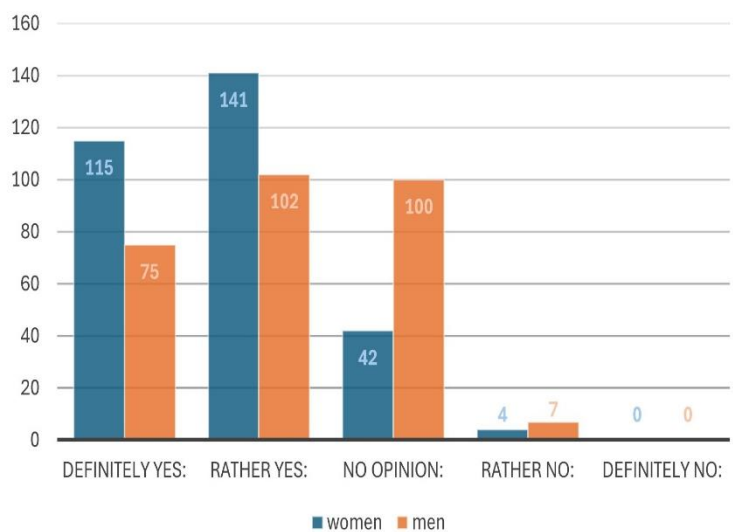


Fig. 6. Gender-based distribution of responses to the analyzed questions regarding the evaluation of the "Green Healing" program's organization

Source: data based on the survey's results conducted by the City Greenery Authority in Poznań

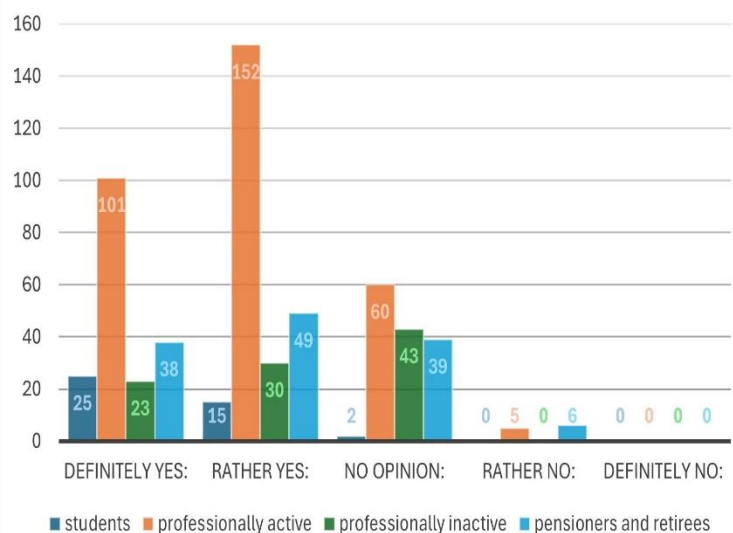


Fig. 7. Distribution of responses by employment status to the analyzed questions regarding the evaluation of the "Green Healing" program's organization

Source: data based on the survey's results conducted by the City Greenery Authority in Poznań

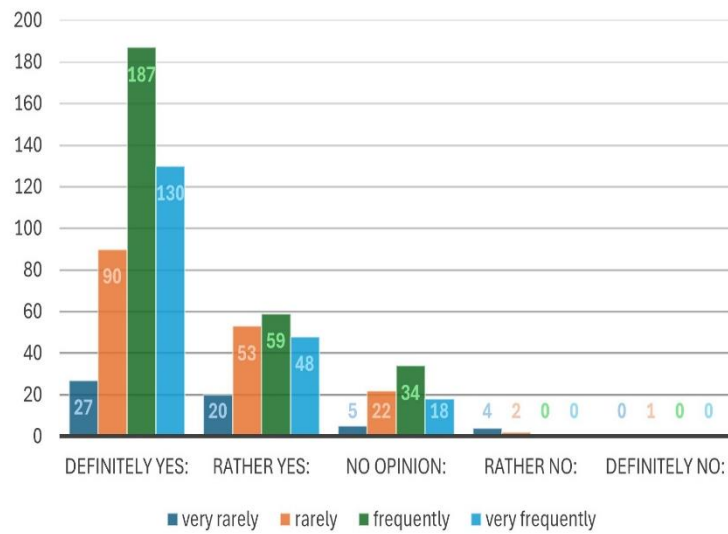


Fig. 8. Distribution of responses by frequency of hospital stays to the analyzed questions regarding the evaluation of the "Green Healing" program's organization

Source: data based on the survey's results conducted by the City Greenery Authority in Poznań

## Summary

The survey investigated several dimensions of the program's impact. First, regarding the expansion of knowledge, approximately 70% of participants reported that the lecture "definitely" broadened their understanding. Noteworthy differences emerged by gender—with slightly more women affirming this benefit—and by professional activity, as a higher number of employed individuals reported definite knowledge gains compared to students. Similarly, among those frequently or very frequently hospitalized, 78.6% and 67.5% (respectively) confirmed knowledge improvement, while even those with rare hospitalizations showed high positive responses (83.3% and 75% in the "definitely yes" or "rather yes" range).

When evaluating improvements in physical and psychological well-being, the participants predominantly chose "definitely yes" for both aspects, with more than half of all groups affirming a positive impact. In particular, physically, 68% of the frequently hospitalized group reported significant improvement, and similar favourable trends were observed for mental well-being. The results suggest that those who have more regular contact with healthcare services are especially receptive to the psychological and educational benefits of such interventions.

The study also assessed whether the lecture was perceived as a valuable addition to the participants' hospital stay. Here, 61% of respondents indicated that it was "definitely" a beneficial supplement, reinforcing the view that even if the lecture was not the main purpose of their hospital visit, it still added value. Moreover, when asked if they would participate in the lecture again, 79% expressed willingness—with both frequently and very frequently hospitalized individuals showing high levels of readiness (around 71–72.5% "definitely yes"). Additionally, 90% believed that the knowledge gained would be useful in the future, although those with very infrequent hospitalizations tended to show a slightly lower level of commitment to applying the information.

Finally, the evaluation of the program's overall structure covered aspects such as duration, venue, presentation method, content clarity, and the likelihood of recommending the program to others.

For duration, around 71% of participants found it acceptable, with stronger positive feedback coming from females and those in education or employment. Venue suitability received a 70% approval rating overall, and the method of delivery was considered engaging by 72% of the respondents. Likewise, 75% rated the topics covered as interesting, and 80% indicated that the content was clear and understandable. Overall, about 76% of the participants stated that they would recommend the “Green Healing” program to others.

Recent studies on the influence of nature exposure on health confirm the effectiveness of such interventions. A methodological review *Current Methodologies of Greenspace Exposure and Mental Health Research – a Scoping Review* highlights that direct experiences in natural settings yield even stronger positive outcomes for mental well-being than virtual exposures, and regular access to greenspaces is associated with improved mood and reduced stress levels [4]. These findings align with the present study, further supporting the need to develop nature-based programs as a valuable component of patient care and recovery processes.

In summary, the research demonstrates that the “Green Healing” program is highly regarded by its participants. It effectively increases knowledge, improves both physical and mental well-being, and is valued as a supplementary treatment, especially among those who frequently use hospital services. The uniformly positive responses—across various demographic and health-status groups—strongly support the program’s role as a beneficial, integrative approach to patient recovery.

## Acknowledgements

The authors would like to thank the Poznań City Greenery Authority for sharing the survey results and enabling their analysis.

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## THE IMPACT OF PHYSICAL ACTIVITY ON THE QUALITY OF OFFICE WORK

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### **Abstract:**

The study analyzes the impact of regular physical activity on the quality of office work in the context of aspects such as problem-solving, decision-making, task planning, punctuality, and motivation. The research, conducted among 57 office employees with a predominance of women, used a proprietary questionnaire. The results show that individuals who regularly engage in physical activity more often demonstrate higher problem-solving skills, are more independent in decision-making, organize and plan their work more effectively, and display greater punctuality and motivation. The effects are most noticeable with increasing frequency and duration of activity sessions. The findings confirm that incorporating regular physical activity into daily life is an effective way to improve both professional performance and the psychophysical well-being of office employees.

### **Keywords:**

*physical activity; quality of office work; motivation; problem-solving; professional efficiency*

### **Introduction**

The modern world of work presents employees with increasing challenges and demands regarding creativity, efficiency, and above all, stress resilience. The rapid development of technology, time pressure, and growing competitiveness in the job market expose workers to numerous stressors, which can lead to decreased motivation and deterioration in overall psychophysical condition. In response to these challenges, increasing attention is being paid to the role of physical activity in enhancing both individual well-being and professional performance.

Physical activity plays a key role in the prevention of lifestyle diseases such as obesity, diabetes, and cardiovascular diseases. However, its role is not limited to health aspects alone. Systematic, regular physical effort improves cognitive functions, supports concentration and creative thinking, and increases stress resistance. All these elements have a direct impact on professional efficiency and thus on the level of satisfaction with daily duties.

Our study was conducted in the form of a questionnaire divided into two parts. In the first part, respondents answered questions related to the frequency, duration of individual "sessions," and type of physical activity undertaken. The second part of the questionnaire was based on a four-point Likert scale, where participants responded to questions regarding specific qualitative aspects of their job

performance (ease of problem-solving, decision-making skills, task planning, timely task execution, and motivation to work).

The responses on the applied Likert scale were as follows:

- Definitely yes
- Rather yes
- Rather no
- Definitely no

## General Statistics

The study involved 57 office workers, among whom women predominated, accounting for 63% (36 people) of the total group, while men represented 37% (21 people). No responses indicating another gender identity were recorded in the sample. This structure reflects the typical gender distribution in office environments, enabling analysis of potential differences in physical activity and work quality with this aspect in mind.

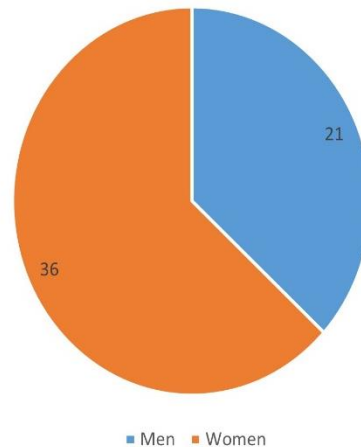


Fig. 1. The ratio of men and women  
Source: results of the authors' own survey

The majority of respondents, as many as 86% (49 people), work standard daytime hours, while only 14% (8 people) declared working in a shift system. This result indicates that the study group consists mainly of individuals employed in a traditional office work model, which is significant when interpreting the impact of physical activity on work quality, especially in terms of regularity and opportunities for physical activity outside of working hours.

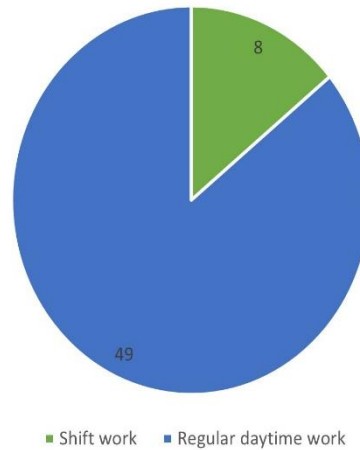


Fig. 2. The ratio of shift workers to employees working standard daytime hours

Source: results of the authors' own survey

When asked to indicate up to two of the most frequently performed physical activities, the most commonly chosen form of exercise was walking (27 people, 48%). Other popular activities included cycling (19 people, 33%) and gym/fitness (15 people, 26%). Running was chosen by 6 people (10%), dancing and other forms of activity by 5 people each (9%). Team sports attracted little interest in the surveyed group, with only 3 people (5%), and swimming was chosen by 2 people (3%). Notably, 10 people (17%) reported not engaging in any additional physical activity. This diversity allows for an analysis of the relationship between type and frequency of physical activity and selected qualitative aspects of office work.

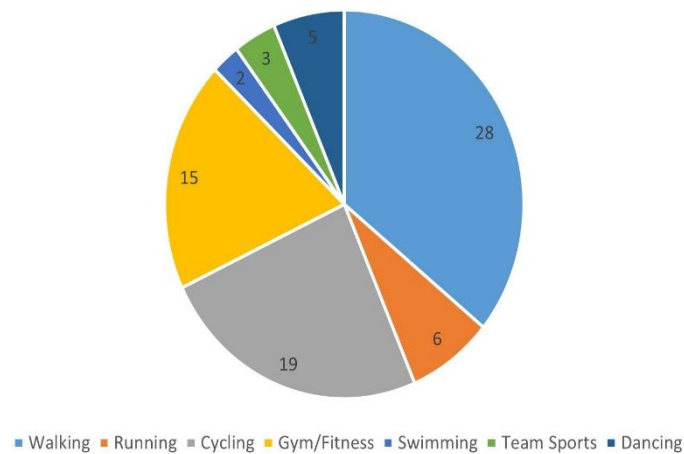


Fig. 3. The distribution of different types of physical activity among the respondents

Source: results of the authors' own survey

## Physical Activity and Problem-Solving Skills

An important issue analysed was the ability to cope with difficulties during work. In particular, the study assessed whether regular physical activity is associated with easier problem-solving and greater flexibility in the face of professional challenges.

Among those who are physically inactive, as many as 40% reported frequent problems with solving work-related issues. In contrast, individuals who are regularly active 1 to 3 times a week reported such difficulties much less often—only 9% of respondents. In this group, nearly 30% responded “definitely not,” indicating a very good ability to resolve dilemmas. Among those exercising 4 to 6 times per week, no one reported difficulties of this kind.

Analysis showed that participants engaging in physical activity for 30 to 60 minutes handled work problems well in over 91% of cases. Those who engaged in shorter forms of movement reported such issues in only 15% of cases. Again, the most physically active group, with individual sessions exceeding an hour, reported no difficulties, with one in four respondents saying “definitely no”. This suggests that regular physical activity may support effective decision-making in office environments, with longer activity sessions being associated with better problem-solving abilities.

These findings are consistent with those of Guiney and Machado (2013), who in their literature review demonstrated that regular aerobic activity significantly supports the development of executive functions in healthy individuals. The authors emphasized a strong body of scientific evidence confirming the positive effects of systematic exercise on planning, organization, cognitive flexibility, and effective problem-solving [1]. This consistency supports the notion that regular physical activity is a key factor in dealing with cognitive and professional challenges, confirming its positive impact on problem-solving abilities in office work settings.

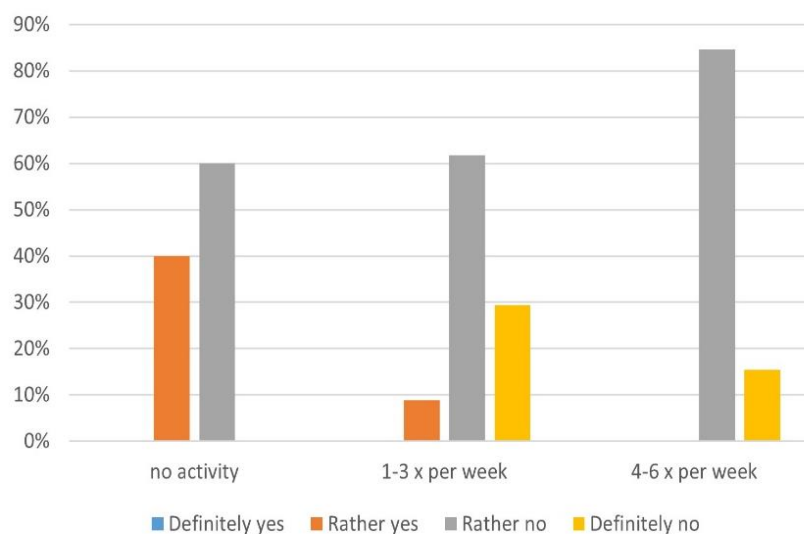


Fig. 4. The relationship between the frequency of physical activity and responses to the question "Do you have any difficulties in problems solving?".

Source: results of the authors' own survey

## Physical Activity and Decision-Making

Respondents were asked: “Do you find decision-making difficult?” Individuals who do not engage in any physical activity were more likely to report difficulty in decision-making. In this group, responses “rather yes” or higher accounted for as much as 60%. As exercise frequency increased (especially 1–3 times per week), there was a proportional rise in the number of individuals reporting no decision-making difficulties. In this group, the responses “rather not” accounted for 50% and

“definitely not” for about 32%. Thus, the majority of those who find decision-making easier exercise regularly—around 90% of all participants.

A similar trend was observed in the duration of physical activity. Respondents exercising for 15–30 minutes more often reported difficulties, while those in the 30–60 minute and longer groups rarely or never reported such issues (in 90% of cases).

According to Y. Fang, T. Xu, M. Ye, and C. Li, regular physical activity improves cognitive functions and significantly influences self-efficacy in decision-making, indirectly related to increased self-control and reduced social anxiety [2]. Studies by both psychologists and neuroscientists have shown that regular physical effort improves memory, attention, and the speed of information processing, directly affecting work quality.

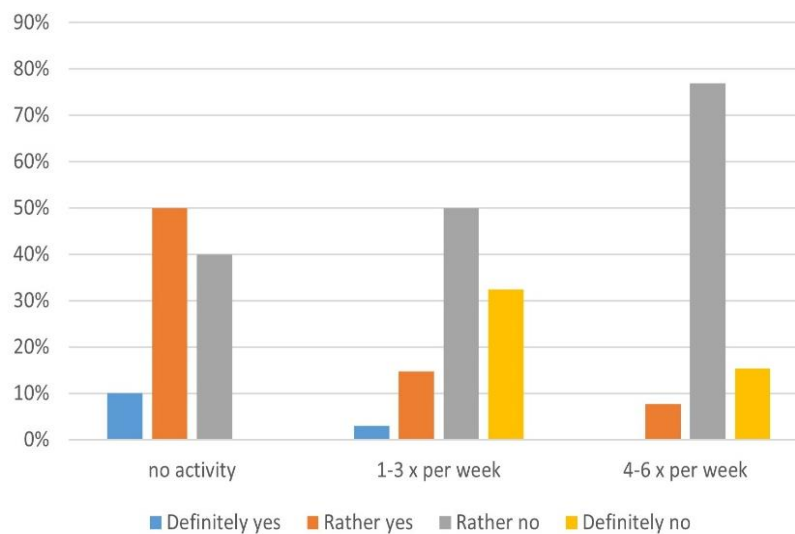


Fig. 5. The relationship between the frequency of physical activity and responses to the question "Do you have any difficulties in decision making?".  
Source: results of the authors' own survey

## Physical Activity and Task Planning

Engaging in additional physical activity during the day is often a personal commitment for many people. Regular fulfilment of this commitment usually requires a well-thought-out plan, often including aspects like proper nutrition, routine monitoring of body parameters, etc. This regularity typically results from developing long-term self-discipline—an outcome of following one’s plan daily [3]. Thus, effective planning is directly related to self-discipline and, indirectly, to goal achievement. People who are physically active should therefore also be good planners to achieve their goals. Skilful planning is key to personal and professional success—proper task scheduling reduces the risk of delays, errors, and helps adapt to sudden changes in duties.

Among survey participants, 60% of physically inactive individuals responded “rather not” or less to the question on planning, with no one answering “definitely yes.” This clearly shows that most people who do not engage in additional exercise rarely plan their work duties or do so irregularly. In contrast, among the largest group—those exercising 1 to 3 times a week—fewer than 12% rarely planned their work, with none answering “definitely not.” About 88% of this group identified as

planners, including 10 people (approx. 30%) who answered “definitely yes,” indicating regular planning. Among those exercising 4 to 6 times a week, no one reported not preparing or rarely preparing plans. All respondents in this group answered “rather yes” or higher, with 7 people (around 54%) saying “definitely yes”.

Regarding the duration of single activity sessions, those exercising for 15–30 minutes mostly responded “rather yes” (approx. 70%). Among those training for 30–60 minutes, almost 96% planned their work, and in the over 60-minute group, about 94% did so. Notably, half of the over-60-minute group answered “definitely yes,” compared to 30% in the 30–60-minute group.

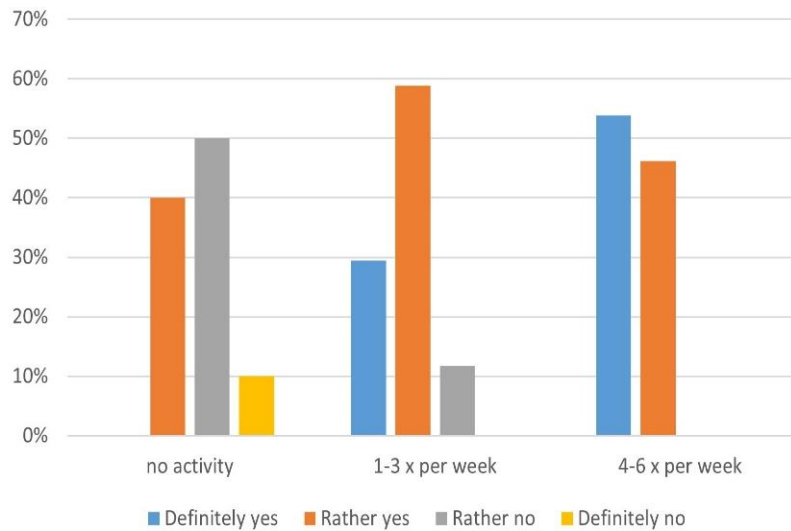


Fig. 6. The relationship between the frequency of physical activity and responses to the question "Do you plan how you carry out your work tasks?".  
Source: results of the authors' own survey

## Physical Activity and Punctuality

One of the key aspects of work quality in office settings is the timely execution of responsibilities. The study analysed how the frequency and duration of physical activity affect employees' ability to complete tasks on time.

Survey results showed that most office workers declared timely task execution, with the level of this ability varying by frequency and duration of physical activity.

The highest proportion of “rather yes” and “definitely yes” responses—indicating punctuality—was found among those regularly engaging in physical activity, suggesting a beneficial effect of exercise on professional functioning. Among inactive office workers, only one in five admitted to frequently missing deadlines. However, none of them responded “definitely yes,” unlike the regularly exercising group. While most respondents reported generally completing their tasks on time, regular punctuality increased with exercise frequency.

Among those spending 15–30 minutes on physical activity, the dominant answer was “rather yes,” indicating relatively low consistency in timely execution. The situation improved among those training for more than 30 minutes, with almost 43% reporting regular punctuality.

The study “*The Interrelationship Between Physical Activity Intensity, Cardiorespiratory Fitness, and Executive Function in Middle-Aged Adults: An Observational Study of Office Workers*” found that individuals engaging in regular, higher-intensity physical activity and possessing better cardiorespiratory fitness demonstrate higher executive function. This translates into more effective planning, organization, and task execution [4]. The alignment of these findings with our own confirms that systematic physical activity supports timely task completion in office work environments.

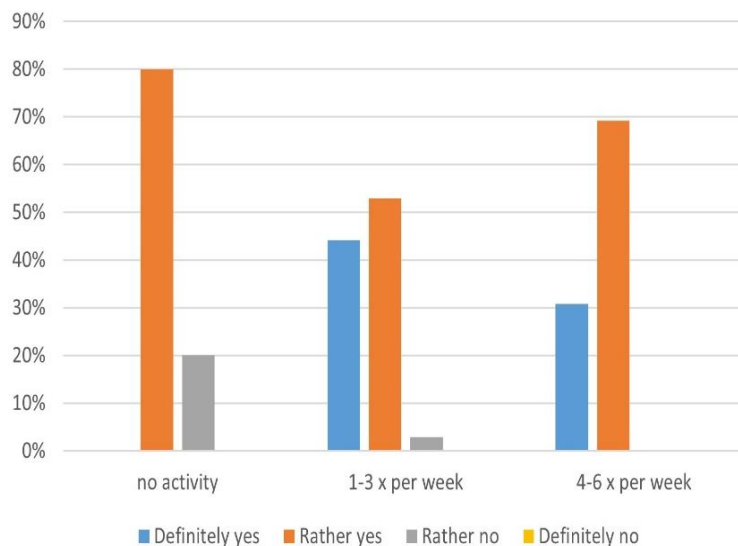


Fig. 7. The relationship between the frequency of physical activity and responses to the question "Do you complete your work tasks on time?".  
Source: results of the authors' own survey

## Physical Activity and Work Motivation

Motivation to perform various tasks, including professional ones, depends on many variables. We are certainly more willing to take on tasks when we are in a good mood, feel confident, can concentrate, and experience less stress—all of which are indirectly linked to physical activity. Regular exercise stimulates the release of endorphins, natural painkillers that create a sense of euphoria. This, in turn, contributes to improved mood and significantly reduced stress. Additionally, people who regularly engage in physical activity often observe progress in achieving their personal goals, which builds self-esteem and confidence. At the same time, brain health is supported through increased blood flow and better oxygenation, improving concentration and cognitive functions [5].

Among physically inactive respondents, as many as 70% rarely feel motivated to perform their work duties, with no one responding “definitely yes”—indicating a lack of consistent determination. The picture was different for the group exercising 1 to 3 times a week, where over 76% felt motivated to work, including 4 individuals who reported regular motivation. Among those exercising 4 to 6 times a week, no one reported a lack of determination, and 30% of this group reported daily motivation.

Regarding workout session length, among those exercising 15–30 minutes, over 70% felt motivated. Among the 30–60-minute group, over 83% reported feeling determined, and in the group exercising for more than an hour, over 87% felt motivated, with 4 people (25%) reporting unwavering motivation—responding “definitely yes”.

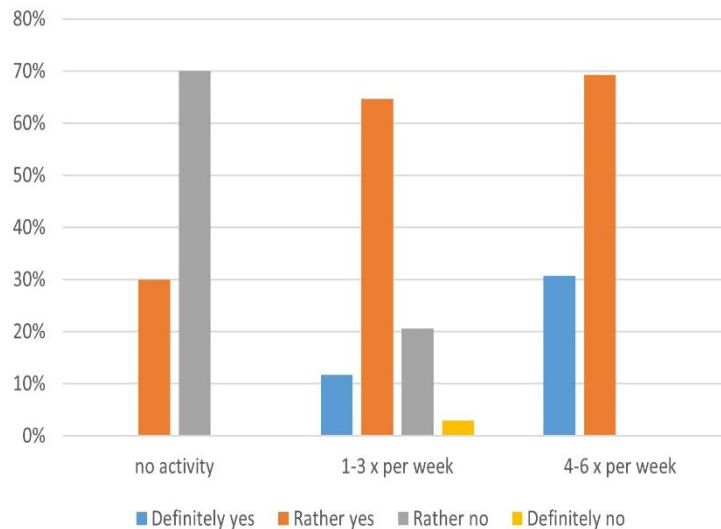


Fig. 8. The relationship between the frequency of physical activity and responses to the question " Do you feel motivated to work?".  
Source: results of the authors' own survey

## Summary

The article explores the relationship between regular physical activity and the quality of work among office employees, focusing on elements such as problem-solving, decision-making, task planning, punctuality, and motivation. In the context of increasing workplace demands and stress, the study highlights physical activity as a supportive factor for both mental well-being and professional performance.

The findings indicate a clear positive correlation between physical activity and the ability to function effectively at work. Individuals who engage in regular exercise demonstrate better problem-solving skills, make decisions more confidently, and are more likely to plan and complete their tasks on time. Furthermore, physical activity appears to significantly enhance internal motivation, which is crucial for maintaining engagement and productivity in the workplace.

Importantly, the study shows that both the frequency and duration of physical activity matter. More consistent and longer exercise sessions tend to be associated with stronger benefits in all examined areas. These results align with existing scientific research confirming that regular physical activity supports cognitive flexibility, emotional regulation, and self-discipline—all of which are vital for high-quality work performance.

In conclusion, integrating physical activity into one's routine can be an effective strategy not only for improving health but also for strengthening key professional competencies and increasing overall job satisfaction. Physically active office employees are more resilient to stress, cope better with the demands of the modern job market, and are significantly less likely to experience professional burnout.

## Literature

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## REVIEW ON THE MICROENCAPSULATION OF VEGETABLE OILS

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### Abstract:

The main causes of oxidation reactions in fat products are oxygen, heat, light and moisture. The oxidation of unsaturated fats in particular is a major problem. In recent years, natural or synthetic antioxidants have been widely used to retard oxidative degradation. Encapsulation of oils is becoming a promising method of oil preservation, which improves the functional properties of oils but also protects them from unwanted oxidation. Due to its versatility and effectiveness, microencapsulation has been widely used and commercialised, especially in the encapsulation of marine oils, vegetable oils and essential oils. A wide range of encapsulation techniques are used. This review presents the most commonly used oil encapsulation methods.

### Keywords:

*encapsulation; vegetable oils; methods*

### Introduction

Vegetable oils are playing an increasingly important role in the development of commercial applications due to their wide availability, low cost, biodegradability and environmental friendliness. The basic constituents of these oils are triglycerides - esters of glycerol with three long-chain fatty acids. These acids can be either identical or different in terms of the structure of the hydrocarbon chain, which typically contains between 10 and 22 carbon atoms [1]. Moreover, the number and position of double bonds in fatty acid molecules significantly affect their physicochemical properties. One of the key factors determining the susceptibility of lipids to oxidation is the degree of unsaturation of fatty acids. The oxidation process can be initiated by a variety of external factors, such as elevated temperature, the presence of light, oxygen or moisture, leading to qualitative degradation of the oil [2]. The consequences include the development of unpleasant tastes and odours, reduced shelf life of products, and the generation of free radicals that can cause adverse physiological effects. To minimise the impact of these factors, microencapsulation techniques are commonly used not only to protect the oils, but also to mask their odour and taste and to release them in a controlled manner [3].

Microencapsulation is the process of encapsulating one or more substances (such as a base ingredient, active substance or separate phase of a mixture) inside one or more surrounding materials, such as coatings, polymer matrices or carriers. The aim of this process is to protect the encapsulated substance from the adverse effects of biotic and abiotic agents. This technique is particularly effective in protecting fatty acids and accompanying vitamins from oxidative degradation. The effectiveness of microencapsulation, as well as the stability of the core and its physicochemical properties, are largely determined by the nature of both the core substance and the encapsulating material [4].

The available microencapsulation techniques can be classified as physical, physicochemical as well as chemical methods. The choice of the appropriate method depends primarily on the properties of the active substance, the type of envelope material and the intended end use [5].

The aim of this review is to discuss the most commonly used methods for microencapsulation of vegetable oils. First, the basics of the different techniques, their operational parameters and key advantages and limitations will be presented. In the following section, selected representative studies will be presented, with a focus on their main assumptions and potential areas of application.

## MICROENCAPSULATION METHODS FOR VEGETABLE OIL

### Physical methods

Physical methods involve the mechanical formation or compaction of the envelope material around the core of the microcapsule. These techniques are of great interest in the modern food industry due to their simplicity of execution and low operating costs. In practice, they are often combined with physicochemical or chemical methods, e.g. by using a drying process after the actual microencapsulation step [6, 7].

#### *Spray drying*

Spray drying is one of the most commonly used methods for microencapsulating vegetable oils. This technique allows liquid systems such as solutions, suspensions or emulsions to be converted to solid form. The process is based on the introduction of a pressurised liquid into a spray nozzle, where it is broken down into microscopic droplets within a drying chamber. The substance forming the encapsulating matrix - usually a polymer - is in the continuous phase of the respective system. During drying, the dispersed droplets encounter a stream of hot air, which provides heat energy by convection, leading to the rapid evaporation of much of the solvent. This results in the formation of powder particles, which are then separated from the air by cyclone or bag filters. Both the physical properties of the emulsion and the atomisation parameters play a key role in the efficiency of the entire process - they affect, among other things, particle and droplet size, encapsulation efficiency, physicochemical characteristics of the final product, its yield and stability during storage [6, 8]. In the case of oil microencapsulation, the first step is to prepare the emulsion by dispersing the oil in a polymer solution. Various forms of oil-in-water (o/w) emulsions are used here, both monolayer and multilayer.

The atomisation parameters are related to the characteristics of the drying device and include inlet and outlet temperatures, material feed rate, flow rate and type of spray gas, and nozzle diameter [9-11]. Under laboratory conditions, it is possible to fine-tune these parameters to control the properties of the particles obtained. It is possible to adjust the process by changing the drying mode,

type of atomiser or air flow rate. However, on an industrial scale, this flexibility is limited due to high costs and technological complexity [12].

This method has a number of advantages over other microencapsulation techniques. These include the easy availability of suitable equipment on an industrial scale, the possibility of using a variety of envelope materials, the potential for large-scale production, simple equipment design, high process efficiency and relatively low operating costs. The main limitations of spray drying in the context of microencapsulation include the small number of compatible wall materials, which must have good solubility in water. In addition, the final product often takes the form of a fine powder, which may require further processing - for example to break up the resulting agglomerates. Another disadvantage of this technique is the relatively low content of active substances in the microcapsules [6, 7].

### Freeze-drying

Also known as lyophilisation, it is one of the most commonly used microencapsulation methods, especially for heat-sensitive substances. It is an effective alternative to spray drying, especially for the production of oil-containing formulations. With this technique, it is possible to obtain microparticles characterised by high resistance to thermal degradation and oxidation, as well as good encapsulation efficiency. The freeze-drying process involves lowering the temperature of the material below the freezing point and then removing water by sublimation under reduced pressure - below the triple water point [13]. The whole process is divided into three main phases:

- freezing – which is the conversion of most of the water into ice and the formation of an ice crystal network;
- primary drying – involving sublimation of the ice;
- secondary drying – i.e. removal of the remaining bound water through desorption [14].

It is the freezing stage that plays a key role in shaping the morphology of the final product. During it, ice crystals are formed, the size and distribution of which affect the essential properties of the dried material - including its structure, speed of the drying process, crystallinity, specific surface area, and ability for subsequent reconstitution [14].

Primary drying is the second stage of the freeze-drying process and is closely linked to the earlier freezing phase. Ice sublimation starts from the top layer of the sample and progresses towards the bottom of the sample. In the case of fast-frozen samples, where fine ice crystals are formed, the flow of water vapour through the dry layer is impeded, which can significantly increase the time of this stage. Slower freezing, on the other hand, leads to the formation of larger ice crystals, which form a more permeable structure, allowing faster transport of water vapour and thus reducing the pre-drying time. During this phase, water is removed in the form of ice by sublimation, i.e. a direct transition to a gaseous state. The efficiency of this process depends mainly on the temperature of the heating shelf and the pressure in the freeze-drying chamber. By adjusting these parameters appropriately, the duration of primary drying can be optimized [15].

Secondary drying is the final stage of freeze-drying, in which the remaining bound water in the product - that which did not freeze during freezing and was not removed during sublimation - is eliminated. During this stage, the shelf temperature is further raised, while maintaining a low pressure - sometimes lower than during primary drying. The aim of this stage is to remove the adsorbed moisture that is still in the structure of the dried material, through a process of desorption [16, 17].

The greatest advantage of freeze-drying is the formation of a porous material structure as a result of sublimation of the ice crystals, which promotes easy and efficient hydration of the powdered product. Freeze-dried particles are usually of high quality. However, certain limitations of this method, such as the long duration of the process, the need for batch production, the use of low temperatures, the high level of vacuum and significant operating costs, hinder its widespread use on an industrial scale. The aim of this step is to remove the adsorbed moisture that is still in the structure of the dried material, through a desorption process [18].

### **Physico-chemical methods**

Physicochemical methods are based on electrostatic interactions between the components of a given system, which can be modified by mechanical agitation, changing the pH or temperature. Such actions lead to the development of a firm and stable particles. The properties of the droplet - such as phase composition, surface charge, thickness of the protective layer and resistance to external agents - can be adjusted through precise control of the formulation composition and its manufacturing conditions. After the physicochemical treatment step, the particles are usually subjected to a drying process, such as spray drying or freeze drying. This not only improves their stability and shelf life during storage, but also results in a product with improved functional properties [19].

### Coacervation of complexes

Coacervation is the term used in colloid chemistry to describe the process of association phase formation induced by modification of the environment (pH, ionic strength, temperature and solubility) under controlled conditions. Complex coacervation is a liquid-liquid phase separation phenomenon that occurs between oppositely charged polymers through electrostatic interactions. Complex coacervation works in microencapsulation by forming a barrier around the active material and preventing physical and/or chemical interactions of the active compounds with the external environment. This microencapsulation technique has proven to be particularly effective in stabilising unsaturated lipids and providing the product with consistent sensory stability [20].

Compound coacervation is a process that occurs in a three-component system consisting of a solvent, an active substance and a coating material. In the case of emulsions, the process can be divided into four main steps:

- preparation of an aqueous solution containing two or more polymers and the addition of a hydrophobic phase containing the active substance - often using a protein polymer solution - followed by homogenisation of the mixture to obtain a stable emulsion,
- adjusting the pH so that each polymer acquires a characteristic electrostatic charge,
- lowering or raising the temperature to a level that allows coacervation and phase separation to commence,
- curing the polymer coating by applying high temperature, a precipitating (desolvation) agent or a crosslinking substance [6].

The encapsulation process based on electrostatic interactions is influenced by many operational parameters, such as ionic strength, pH, composition and concentration of the encapsulating matrix, charge distribution, homogenization technique, solubility of macromolecules and other molecular characteristics resulting from the physicochemical properties of the solution. Therefore, an in-depth understanding of these factors is crucial for more efficient coacervation and its optimal use.

Although the main driving force behind coacervation is electrostatic interaction between oppositely charged molecules, van der Waals forces and hydrophobic interactions also play an important role, especially when proteins are present, further complicating the nature of the process [21].

Once the coacervate is formed, the microcapsules are subjected to drying to improve their stability and extend their shelf life. The most commonly used drying methods are spray drying and freeze drying. The choice of the appropriate technique depends on the properties of both the active substance and the capsule material used. Compound coacervation is a traditional and well-known microencapsulation method that offers numerous advantages - including milder process conditions, lower equipment costs and the ability to obtain capsules with a high active substance content. Nevertheless, the technique also has some limitations, especially when encapsulating less stable compounds, such as oils. One of the main difficulties is the need to maintain strict pH and ionic strength conditions under which the coacervates remain stable. To prevent the system from disintegrating, it is often necessary to rapidly crosslink the coacervate shortly after its formation. An additional challenge is the complex and time-consuming optimization process - since many process parameters can significantly affect the physicochemical properties of the system during complex coacervation [22].

### Ionic gelation

Ionic (ionotropic) gelation is a microencapsulation method that uses an aqueous polymer solution in which low-molecular-weight ions interact with oppositely charged polyelectrolytes, leading to the formation of an insoluble gel. This process can be used to encapsulate both hydrophilic and hydrophobic compounds. The active ingredient is dissolved, dispersed or emulsified in a polymer solution, and then the solution is introduced in droplet form into a bath containing the appropriate ions. As a result of this interaction, spherical gel structures are formed, in which the active material is trapped in the polymer matrix [23].

This technique has found wide application with natural polysaccharides, allowing to obtain biocompatible and biodegradable products. The most commonly used biopolymer in the ionic gelation process is sodium alginate, valued for its gelling ability and favorable chemical structure. Due to the presence of carboxyl groups, alginates easily form gels in the presence of calcium ions or other divalent and trivalent cations. In particular, the high content of guluronic acid (guluronate) in the alginate structure promotes the formation of more robust gels [24].

This method is characterized by simplicity, low cost and ease of application in the encapsulation of various substances. It does not require the use of specialized equipment, high temperatures or organic solvents, which makes it particularly attractive from a technological and environmental point of view. Its advantages also include the ability to use aqueous solutions, obtain fine particles, and precisely control their size by adjusting the concentration of the starting solution accordingly. In addition, the technique makes it possible to encapsulate a wide range of compounds, both hydrophilic and hydrophobic, in a gel [6].

Limitations of this method include the need for a gel bath, the complexity of formulation development, the time-consuming nature of the process, and low reproducibility under small-scale conditions. However, the use of vibrating nozzle technology (NVT) can significantly improve the homogeneity of the particles obtained and increase the scalability of the process. In addition, ionic

gelation can be carried out under mild, non-toxic conditions, which preserves the structural and functional integrity of even highly sensitive bioactive substances [6].

Ionic gelation can be successfully combined with vibrating nozzle technology (NVT), used in selected types of equipment. NVT makes it possible to form droplets of uniform size by introducing controlled vibrations into the liquid stream flowing through a precision-made nozzle. The frequency of these vibrations determines the number of droplets generated per unit time. This technology is attracting increasing interest, mainly due to the possibility of obtaining microspheres with high reproducibility and well-defined sizes, which translates into homogeneous and monodisperse particles. For the process to be optimal, it is necessary to precisely determine key operating parameters, such as the speed of the liquid flow, the frequency and amplitude of the vibrations, and the applied electrode voltage [25].

#### Electrostatic layer-by-layer deposition

In electrostatic layer-by-layer deposition, the process begins with the application of an ionic emulsifier, which, during homogenization, quickly adsorbs onto the surface of the lipid droplets to form a primary emulsion with fine droplets. An oppositely charged polyelectrolyte is then introduced into the system, which binds to the surface of the droplets to form a secondary emulsion in which the lipid particles are surrounded by a bilayer. This procedure can be repeated many times, making it possible to create oil droplets coated with an interface containing three or more superimposed polymer layers. Polymer layers deposited in this way increase the stability of the microdroplets, protecting the encapsulated substances from environmental factors such as pH changes, ionic strength, freezing and heating cycles. As a result, these systems show better protective properties and performance than their uncoated counterparts [6].

Layer-by-layer deposition technology is characterized by simplicity, high flexibility and the ability to form multilayer coatings as needed. A key element in its design is the evaluation of the ionic properties - that is, the electrical charge - of the emulsifier and individual biopolymers, depending on the pH of the environment. This makes it possible to determine the optimal conditions conducive to electrostatic interaction between the components. The efficiency of the method can be significantly improved by controlling the number, type and sequence of biopolymer layers applied to lipid droplets. This makes it possible to precisely shape the thickness, composition, charge, permeability and consistency of the interfaces obtained. After the layer deposition process, it is recommended to use drying techniques that convert the emulsion into powder form, which facilitates storage and further use of the material. The most commonly used methods are freeze-drying (sublimation drying) and spray drying [26, 27].

Multilayer emulsions show great potential in food and cosmetic applications, as their structure provides a number of important benefits. These include protection of fat droplets from oxidation and aggregation, the ability to release active ingredients in a controlled manner, and increased resistance to environmental factors due to the presence of thicker, more stable interfacial layers. Electrostatic layered deposition thus provides a versatile tool for modifying the properties of interfaces in emulsions, which translates into their functionality and effectiveness as carrier systems. In addition, the multilayer structure provides better protection of active ingredients from thermal stresses that can occur during drying processes such as freeze-drying and spray-drying. Despite its many advantages, the technology also faces some limitations that may hinder its widespread industrial

implementation. This is because it requires careful selection of ingredients and strict control of process parameters to avoid unfavorable phenomena such as droplet bridging, continuous phase depletion and emulsion destabilization. The complexity of the system and its associated costs can be a barrier to implementation, but in many cases the anticipated benefits - such as increased stability or extended active ingredient duration - may justify the investment [28, 29].

### **Chemical methods**

Chemical methods differ from physicochemical methods in that they are based on chemical reactions - most often polymerization - leading to the formation of a coating with specific mechanical and chemical properties, which increases the stability and efficiency of the encapsulation process. Of the various approaches, these techniques are used the least frequently, mainly because of the need to fine-tune the reaction conditions so that the encapsulated bioactive substance does not degrade or lose activity. In addition, chemical methods tend to be more labor-intensive and strongly dependent on process parameters, such as the type of emulsifier used, the intensity of mixing, the mass ratio of core to matrix, the pH of the environment, the temperature of the reaction, or the surface hydrophobicity of the core material [30].

#### Interfacial/in situ polymerization

Interfacial (in situ) polymerization is a microencapsulation technique in which the active material is encapsulated in microcapsules through a chemical reaction occurring at the interface between two immiscible phases. Depending on the solubility characteristics of the encapsulated substance, the process can involve dispersing an oil phase in an aqueous continuous phase or, conversely, an aqueous phase in an organic phase. Each phase contains a different monomer, which reacts with the corresponding monomer present in the other phase. The dispersed phase acts as a good solvent for the monomers, but at the same time as a poor solvent for the resulting polymer. As a result, during the reaction, the system consists of three separate, immiscible components. When the monomers are combined in the system, polymerization reactions are initiated at the interface, leading to the formation of oligomers, which gradually precipitate on the surface of the droplets to form the first coating layer. The polymer formed in this process dissolves neither in the dispersed phase nor in the continuous phase, so it is precipitated and deposited at the interface, forming a permanent microcapsule around each droplet [31].

The interfacial polymerization technique offers a number of potential advantages, such as the ability to precisely control the diameter of microcapsules and the thickness of their coating, achieve a high degree of loading with active material, as well as good, durable mechanical and chemical properties of the resulting coatings. In addition, the method is characterized by low cost, ease of scaling up for industrial production, and the simplicity and reliability of the process itself. Nevertheless, there are some limitations that may hinder its widespread use. One is the need to create an extensive oil-water interface, which can lead to the inactivation of sensitive biological compounds such as proteins or enzymes, affecting their activity during the polymerization process. Another problem can be the presence of unreacted residual monomers in the finished microcapsules, which can react undesirably with the core material, leading to its inactivation or other adverse effects [32].

In situ polymerization is similar to interfacial polymerization, but differs in that the reactants responsible for forming the polymer matrix come from both the continuous and dispersed phases. The process begins with the formation of an oil-in-water (O/W) or water-in-oil (W/O) emulsion through intensive mixing or sonication of the two-phase system. Monomers and reaction initiators are dissolved in one or both phases, depending on the designed microcapsule structure. Since the resulting polymer does not dissolve in the emulsion, the polymerization reaction occurs mainly on the surface of the core droplets. As a result, the polymer begins to be deposited at the interface, forming a thin, closed shell around each droplet - a microcapsule containing the desired material inside. The process of controlled polymer deposition at the interface can be further controlled by changes in pH, temperature, use of precipitants or modification of solvent properties [33].

Although in situ polymerization typically requires a longer reaction time compared to other encapsulation methods, it offers some significant advantages, such as low cost, simplicity of execution and the ability to be easily adapted to industrial scale. However, it is important to note that the effectiveness of this technique depends not only on the properties of the core material and matrix used, but also on the process conditions - including the type of emulsifier, mixing intensity, core/matrix mass ratio, pH, temperature and surface hydrophobicity of the encapsulated material [6].

## Conclusions

This article provides an overview of a selection of commonly used methods for microencapsulation of vegetable oils, taking into account their strengths and limitations. Given the widespread use of microencapsulation in different industrial sectors, it is crucial to have a variety of techniques tailored to specific needs. The literature sources analysed indicate a dynamic development of this field, which allows us to anticipate further technological advances and innovations in the coming years.

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