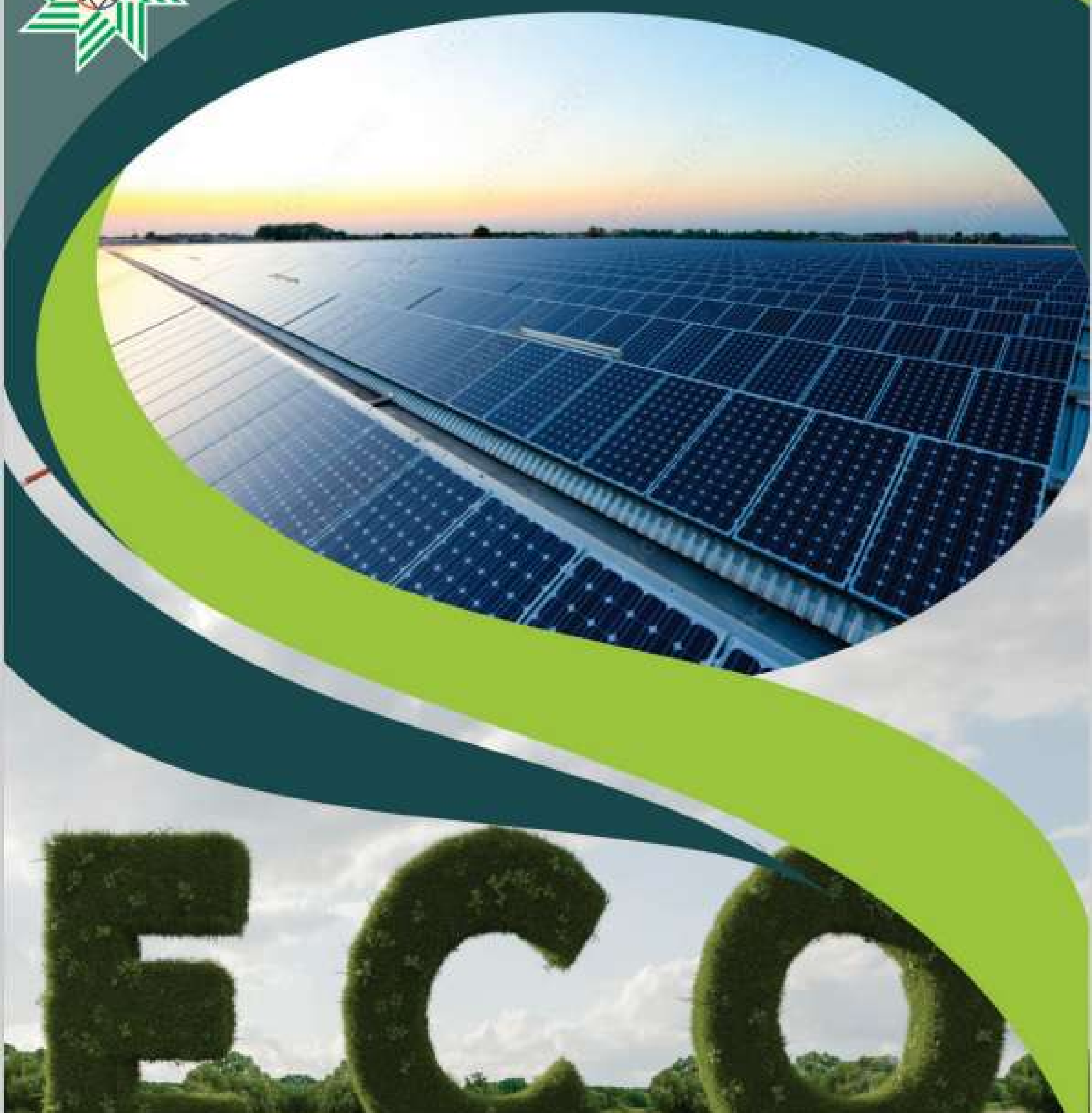

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Energy Sector Vulnerability

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Abstract. The global drone market size is projected to grow at a CAGR of 15.17% during the forecast period 2024-2032, from USD 68.62 billion in 2023 to USD 244.61 billion by 2032. Unmanned aerial vehicles (UAVs) operate without a pilot. They can be remotely controlled or fly autonomously using pre-programmed flight plans and advanced sensors. Drones come in a variety of shapes and sizes, from small consumer models to large industrial applications. They are equipped with a variety of technologies, including cameras, sensors, and communication devices, that enable them to perform a variety of tasks. Common applications of drones include aerial photography, surveillance, agricultural monitoring, and delivery services. As technology continues to advance, the capabilities of drones are expanding, making them increasingly valuable in many industries. The unmanned aerial vehicle market is being fueled by the increasing adoption of UAVs in various sectors, including agriculture, construction, and logistics. The demand for aerial data collection and surveillance, especially in the defense and public safety industries, is fueling the market growth. Furthermore, advancements in drone technology, such as improved battery life, enhanced sensors, and autonomous flight capabilities, are making drones more accessible and effective for commercial use.

Keywords: Drone, flight, investment, application, analysis, global.

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1.Introduction

In recent years, the global landscape has witnessed a significant increase in investments in drone technologies and their associated control systems. This trend is driven by the multifaceted applications of drones in various sectors, including defense, agriculture, logistics, and surveillance. The integration of advanced technologies such as artificial intelligence (AI), machine learning, and autonomous navigation systems has further enhanced the capabilities of drones, making them an indispensable tool in modern operations. The global drone market is estimated to be worth USD 73.06 billion in 2024 and is expected to grow at a CAGR of 14.3% from 2025 to 2030. This growth is mainly driven by the rapid development of drone technology, increasing battery efficiency, AI-powered autonomous systems, and enhanced imaging sensors. This is further expanding the capabilities of drones across industries [4]. These technological innovations are increasing the performance and functionality of drones, allowing them to perform more complex tasks. In addition, the shift towards fully autonomous drones and the introduction of hybrid product systems that combine the strengths of both fixed-wing and multi-rotor designs is expected to further fuel the expansion of the drone industry in the coming years. The increasing adoption of drones in various industries such as agriculture, logistics, construction, and infrastructure inspections is fueling the expansion of the drone industry. The growing need for real-time data collection, monitoring, and control capabilities is one of the key drivers behind this trend. In agriculture, drones are used for crop monitoring, pesticide spraying, and soil analysis, while in logistics, they streamline last-mile delivery. This increase in demand in industrial sectors is expected to be one of the key growth drivers for the drone market in the coming years, especially as drone technology becomes more accessible and affordable [1-7].

2.Analysis

Another significant development in the drone industry is the rise of Drone-as-a-Service (DaaS). Businesses can lease drones and drone-related services instead of purchasing them outright. This model is popular with industrial enterprises that require drone services only occasionally or for specific use cases, such as infrastructure inspections, surveys, or mapping. The ability to access drone technology without a heavy upfront investment democratizes the use of drones and makes them more accessible to small businesses and industrial enterprises with niche needs. There is a growing trend towards small teams managing drone operations. This shift is primarily due to the development of technology that allows small teams to efficiently perform complex aircraft missions. As regulatory frameworks evolve, more companies are gaining approval for advanced operations, including beyond-line-of-sight (BVLOS) missions. This has led to an increase in specialized services, particularly mapping and surveying, which constitute a significant portion of commercial drone applications.

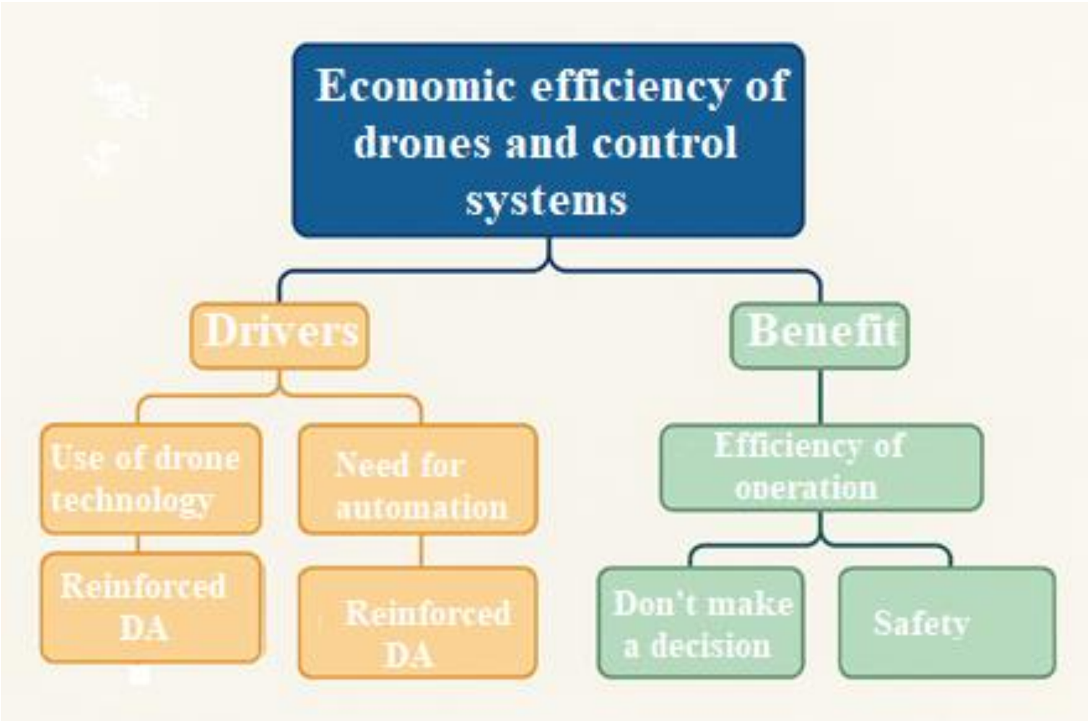

Figure 1. Schematics diagram economic efficiency of drones

The ease of access to sophisticated drone technology allows these small teams to compete effectively, which in turn drives innovation and agility within the drone industry [5]. The growing integration of advanced technologies such as 5G, IoT, and augmented reality (AR) into aircraft operations is fueling the expansion of the drone industry. The inclusion of 5G increases real-time data transmission and control over longer distances. In addition, IoT improves automation and connectivity in applications such as logistics and surveillance. In addition, AR overlays are being used to enhance the user experience in complex tasks such as construction mapping and disaster relief. These technological advancements are not only increasing the operational capabilities of drones, but also expanding their application across various sectors, driving further adoption in both consumer and commercial markets. The defense industry is at the forefront of drone investment, recognizing the strategic advantages offered by unmanned aerial vehicles (UAVs). For example, the United States Air Force plans to invest more than $6 billion over the next five years (2023-2028) in the Joint Combat Aircraft (CCA) program.

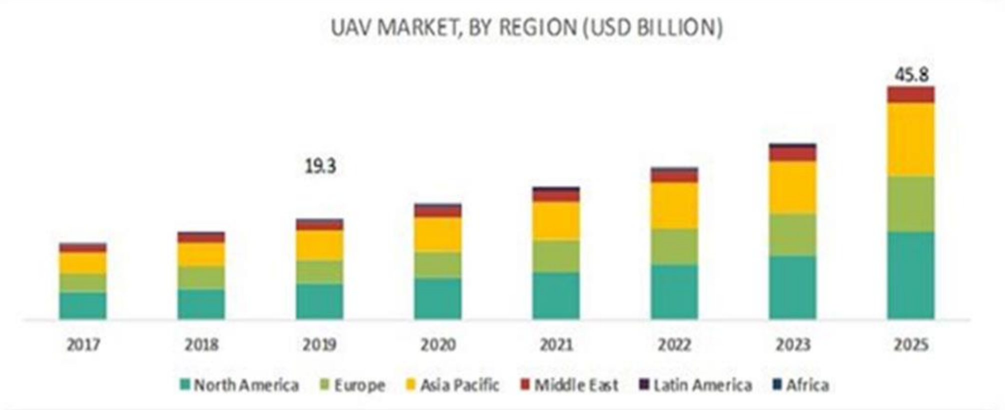

Figure 2. Schematics diagram military

These investments are aimed at developing advanced drone systems that can operate alongside manned aircraft, increasing mission capabilities and reducing risks to human pilots [1]. The diagram of the drone market across countries is shown below. The evolution of drone technology is marked by significant advances in hardware and software components. Improvements in battery performance, propulsion systems, and lightweight materials have extended flight times and increased payload capacities. For example, innovations in lightweight materials and more efficient batteries have allowed drones to perform a wider range of tasks. The integration of artificial intelligence and machine learning algorithms in the technology field has facilitated autonomous navigation, obstacle avoidance, and real-time data processing. These capabilities are crucial for applications that require high precision and adaptability, such as search and rescue missions and infrastructure inspections. The burgeoning drone industry has attracted significant investment from both the public and private sectors. Governments in countries such as the United States, China, and India are allocating funds to improve drone infrastructure and promote local manufacturing. For example, in 2024, the Indian government allocated more than $150 million for drone startups under the Atmanirbhar Bharat initiative [2-6]. Despite promising growth, the drone industry faces regulatory challenges that could hinder its expansion. The lack of standardized regulations across regions can cause confusion and limit companies' ability to operate. Security and privacy concerns also pose significant challenges, with drone-related incidents raising concerns among regulators and the public. The future of the drone industry looks promising with continued investment and technological advancements. Drones are expected to become increasingly integrated into various sectors, leading to increased efficiency, cost savings, and new business models. As the industry evolves, addressing regulatory challenges, ensuring security, and privacy will be critical to maintaining momentum and realizing the full potential of drone technology [3]. Venture capital funding in the drone sector is expected to surpass $2 billion globally in 2023, with private investment also increasing. Companies such as Skydio and Wing have secured significant funding to scale up their operations and develop cutting-edge technologies.

3.Conclusion

The high level of investment in drones and their control systems underscores the transformative impact of this technology across multiple sectors. From enhancing defense capabilities to revolutionizing agriculture and logistics, drones are poised to play a significant role in shaping the future. As stakeholders continue to invest in research, development, and infrastructure, the drone industry is poised to soar to new heights, delivering innovative solutions and driving economic growth.

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Prediction of the impact of ecological factors on plant biodiversity

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Abstract: Climate change is considered one of the main factors in the loss of biodiversity. The presented article analyzes the regional effects of global climate change and the role of these effects in the decline of biological diversity. Based on the results of conducted scientific studies, it is estimated that over the next 100 years in our country, the temperature will increase by 3–6°C and precipitation may decrease by 10–30%. Against the backdrop of future projections, the current state of biodiversity in our country, conservation methods, and efficient usage practices have been discussed, along with recommendations.

Keywords: Climate change, biodiversity, global warming, temperature, precipitation, ecosystem

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1.Introduction

Azerbaijan is located in the eastern part of the South Caucasus, along the western coast of the Caspian Sea, stretching from 38°25' to 41°55' North latitude and from 44°50' to 50°51' East longitude. The country extends approximately 400 km from north to south and 500 km from west to east. The topography of the Republic of Azerbaijan is highly diverse, with two primary landforms dominating the landscape — plains and mountainous areas. About 60% of Azerbaijan's territory is mountainous. The main geomorphological units of the country include the Greater Caucasus, the Lesser Caucasus (including the Karabakh Plateau), the Talysh Mountains, and the Kura-Araz Lowland. The average elevation of the territory is approximately 400 meters.

The climate of Azerbaijan is significantly influenced by its geographical location, topography, and proximity to the Caspian Sea [1]. The area is characterized by semi-desert and arid (steppe), subtropical, temperate, and cold climatic zones. Out of the 11 climate types found worldwide, 8 have been identified in this region.

Climate change is one of the most pressing issues of our time. Unfortunately, Azerbaijan is not immune to these global changes. In the context of modern climate change, significant increases in the number and duration of extremely hot days and heatwaves have been observed during the summer months in Azerbaijan. The assessment of climate change in the Republic of Azerbaijan is conducted at the meteorological stations of the National Hydrometeorological Service under the Ministry of Ecology and Natural Resources. Data from 32 stations have been used to calculate annual temperature and precipitation anomalies. These studies have shown that over the past 20 years, the average temperature across the country has increased by 0.8°C–1.1°C compared to the temperature norms of 1971-2000, with the last decade being the hottest recorded. Additionally, precipitation levels have decreased by 31.1 mm, approximately 3.4%, over the last 10 years.

Azerbaijan is considered one of the most genetically diverse regions in Southwest Asia, serving as a source of valuable plant genetic resources. Among the precious ancestral species found in the country are cereals (wheat, barley, wheatgrass, rye, oats, etc.), legumes (chickpeas, etc.), fruits (apples, almonds, grapes, walnuts, etc.), vegetables (onions, carrots, beets, etc.), and the valuable plant oils and spices derived from them. Additionally, the country's rich intraspecies diversity is well-suited for the successful cultivation of the same species across regions with distinctly different environmental conditions. Azerbaijan is a center of origin and cultivation for many plant species. Its natural flora comprises approximately 5,000 higher plant species, of which more than 40% are wild ancestors of cultivated plants, while only 5% of them are currently cultivated.

Global climate change has a destructive impact on all natural and anthropogenic structures on Earth [2]. Under the influence of global warming, ecological crises are becoming increasingly widespread both temporally and spatially.

In such circumstances, the living conditions for all organisms on the planet are rapidly deteriorating. Consequently, rising global temperatures contribute to increased water scarcity, drought, deforestation, and the expansion of dangerous natural phenomena. As a result, ecosystems are being destroyed, undergoing mutations, and experiencing severe disturbances in natural conditions. The disappearance of favorable conditions leads to the extinction of flora and fauna in affected areas. Global warming not only impacts these systems but also alters the quality of life for the only conscious species on the planet — humans. Over time, the rise in global temperatures, the formation of harsher climatic conditions, and the emergence of a two-season model have a profound impact on human health [3].

2.Analysis

In this research, climate data (2013–2024) were primarily obtained from the official website of the World Meteorological Organization, covering both global and Azerbaijani regions [5]. To study the impact of climate variability on plant diversity, various scientific methods and approaches were used, and an analysis of the Red Books published in Azerbaijan was conducted. In order to ensure the accuracy of the study, the following stages were implemented:

Data Collection: In the research areas, key ecological indicators such as the number of plant species, biodiversity indices (Shannon, Simpson, etc.), species distribution areas, and population density were observed and recorded. Simultaneously, data on temperature, precipitation levels, soil moisture, and other climate variables were collected.

Analysis of Climate and Ecological Variables: Based on the collected data, changes in climate factors were analyzed, and the main factors potentially affecting plant diversity were identified.

Statistical Analysis: The Excel program was used to process and analyze the data. Relationships between climate variables and plant diversity were examined, and multiple regression models were developed to assess the influence of climate factors.

2.1 Analysis of the Impact of Climate Change on Global Plant Diversity

Climate change, especially rising temperatures, has a significant negative impact on global biodiversity. Analyses show that climate change is directly linked to increasing temperatures and decreasing precipitation levels, leading to a 4.2% decline in global biodiversity every decade. This situation disrupts ecosystem functions associated with changes in species distribution areas and deteriorates the living conditions of species. Thus, climate change—particularly temperature rise—shrinks the habitats where species exist and causes some species to go extinct entirely.

Studies indicate that climate change has already led to changes in species distribution areas in many parts of the world. These changes are expected to intensify in the future and result in widespread disruption of ecosystems globally. For example, analyses based on various climate change scenarios across Europe show that many European plant species will be seriously threatened by the end of the century. According to our analysis, more than half of the plant species distributed across Europe will either become vulnerable or endangered by 2080. This will weaken ecosystem resilience and complicate restoration processes.

Forecasted species loss and change under different scenarios suggest that Europe could experience an average of 27–42% species loss and 45–63% species turnover. Regionally, these figures may vary between 2.5–86% and 17–86%, respectively. This indicates that the impact of climate change will continue to vary by region, and biodiversity loss will differ from one region to another. Analyses have shown that species loss and turnover are primarily dependent on the degree of change in two key climate variables: temperature and humidity. This enables a more accurate assessment of climate change impacts.

Mountainous regions are among the most sensitive areas to climate change. Species living in these areas may face losses of up to 60%. At the same time, in some regions—such as boreal zones—very few species will be lost; however, the migration of other species into these areas is expected. The greatest changes are projected to occur in the transitional areas between the Mediterranean and Euro-Siberian regions. This transition will lead to significant shifts in biological diversity due to climate change.

Overall, extinction risks for European plants are increasing significantly, even under moderate climate change scenarios. Some models show that even if climate change is moderate, without appropriate adaptation measures, biodiversity loss will be more rapid and severe. Therefore, serious measures must be taken to effectively combat the impacts of climate change and protect plant diversity.

2.2 Impact of Climate Change on Plant Diversity in Azerbaijan

The growing impact of global climate change and increasingly intense anthropogenic factors, as well as Armenia's occupation of Azerbaijani territories until 2020—which violated international laws and conventions—and the resulting ecological terrorism inflicted on these territories, have caused significant harm to the region's unique biodiversity. If we examine the Red Book, which contains information on the distribution and numbers of biodiversity within the country and plays a major role in protecting Azerbaijan's biological resources, we can see a concerning trend from its first publication to the most recent one (1989–2023): a substantial number of plant and animal species are now under threat of extinction.

In the first edition (1989), the Red Book listed 140 plant species and 108 animal species. In the second edition (2013), despite approximately 30 rare species being removed from the list due to increases in their numbers and distribution areas, the total count more than doubled, reaching 300 plant species and 223 animal species. Unfortunately, in the third edition, the number of pages in the book increased even further due to a rise in the number of rare and endangered species.

In this latest edition, 241 rare and endangered animal species (152 vertebrates, 89 invertebrates; including 39 mammals, 78 birds, 18 reptiles, 11 fish, 7 aquatic invertebrates, 82 insects, and 6 amphibians) and 4,643 plant species (including 6 mosses, 5 algae, 37 fungi, etc.) were included. Unfortunately, these figures are far from encouraging.

Undoubtedly, the consequences of climate change in our country, along with the ecological destruction caused by Armenia's more than 30-year occupation, have played a significant role in this increase.
Rising temperatures and decreasing precipitation levels year by year have directly led to a decline in biodiversity. When we look at climate forecasts related to our country, we see that over the last 100 years, the average temperature has increased by up to 1.3°C, while precipitation has decreased by 31 mm, approximately 3.4% [4, 14].

2.3. Forecasting the Impact of Climate Change on Biodiversity
In Azerbaijan, climate scenarios have been developed based on the MPI-ESM-MR model from the Max Planck Institute for Meteorology in Germany, the GFDL-ESM2M model from the NOAA-GFD Laboratory in the USA, and the HadGEM2-ES model from the Hadley Centre for Climate Science and Services under the UK Meteorological Office. As a result of these calculations, long-term climate data were analyzed, and unique climate scenarios were generated. Using all three models, projections were made for four periods between 1970 and 2100 under the RCP4.5 and RCP8.5 scenarios. The results indicate that by 2100, the average annual temperature across the country will increase by 3–4°C, while precipitation will decrease by 10–30%. It is also predicted that maximum temperatures could reach 47–53°C.
These projections—rising temperatures and decreasing precipitation—will inevitably impact mountainous ecosystems, as well as forests, pastures, and lakes. Additionally, pollution from mining activities, natural disasters, and the expanding scale of anthropogenic impacts from lowlands to highlands will reduce the capacity of these ecosystems to respond to changes. These effects also increase vulnerability among local populations who rely on mountain ecosystems. Most natural disasters pose risks not only to mountain communities and critical infrastructure but also to people living in lowland areas.
Forest ecosystems, which play a crucial role in biodiversity conservation, are also vital for human survival, providing food security, construction materials, fuel (wood, coal), food sources (mushrooms, fruits, nuts, berries), medicinal plants, and grazing lands for animals. Climate change introduces a range of impacts including increased droughts and forest fires, the spread of pests and diseases, emergence of new plant diseases, lengthened vegetation periods due to extreme temperatures, untimely migration in animals, the extinction of aquatic life due to pollution, and the widespread presence of harmful microorganisms in both aquatic and terrestrial environments.
Climate change also exacerbates land degradation and erosion—already intensified by human activities such as overgrazing, deforestation, the conversion of arable land into settlements, and rapid tourism development. These stress factors collectively lead to severe land degradation including erosion and salinization. In this context, climate variability—such as floods and flash floods caused by heavy, intense rainfall and increased extreme weather events—further worsens the situation, leading to serious consequences for both humans and biodiversity.
The rising temperatures and declining precipitation increase the number of areas requiring irrigation and the water demand of agricultural crops, which will result in a reduction of water resources. Azerbaijan is already among the countries struggling with water scarcity [7,8].

3. Conclusion
Taking into account the points mentioned above, in order to minimize the serious and lasting consequences of climate change in our country, the number of relevant state programs should be increased and their areas of implementation expanded. In addition, to ensure future food security, seed banks should be established alongside collection gardens to preserve the genetic resources of crops such as barley, wheat, grapes, pomegranates, etc., under *ex-situ* conditions. Public awareness campaigns should be organized, information on the topic should be regularly published in mass media, and the experiences of other countries with successful outcomes in this field should be utilized. We must not forget that by protecting biodiversity—which enables life for all living beings on Earth—we are also preventing the destruction of our future world.

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Functional Design of Optoelectronic Devices with Enhanced Isolation Capability

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Abstract: This article explores the design and technological features of isolating optoelectronic devices with wide functional capabilities, which have a broad range of applications in modern electronics and automation systems. Operating based on light-based signal transmission, these devices ensure a high level of isolation by eliminating direct electrical current connections, thus playing a critical role in safety and signal quality preservation. The paper presents various types of optoelectronic components, their structural elements, functional expansion possibilities, and areas of application. Engineering challenges encountered during the design process and their solutions are also analyzed. Based on practical examples and simulation results, the effectiveness and reliability of the proposed optoelectronic devices are evaluated. As a result, their potential use in industrial automation, medical equipment, and high-voltage systems is demonstrated extensively.

Keywords: Optoelectronic devices, Isolation, Design, Optocouplers

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1.Introduction

Isolating optoelectronic devices with broad functional capabilities play a crucial role in modern electronics and automation systems, particularly in ensuring safety, maintaining signal integrity, and mitigating electromagnetic interference. These devices operate by transmitting signals via light, thereby eliminating direct electrical connections between two distinct circuits and fulfilling the isolation function. The core structure of such a device typically consists of a photon source (e.g., LED), a light-transmitting medium, and a light receiver (such as a photodiode, phototransistor, or photothyristor). The term “broad functional capabilities” refers not only to simple switching operations but also to analog signal transmission, pulse-width modulation (PWM), various encoding methods, and compensation for temperature or voltage fluctuations. In designing such optoelectronic devices, factors like electrical isolation level (usually measured in kilovolts), switching speed, operating frequency range, and input/output mismatch issues must be taken into account [1-3].

2.Experimental detail

For instance, consider the simplified model shown below:

$$V_{out}=H(f)\cdot V_{in}\cdot e^{-\alpha d} \qquad (1)$$

In this expression, **Vout** represents the output signal, **Vin** the input signal, **H(f)** the frequency-dependent transfer function, **α** the optical absorption coefficient, and **d** denotes the distance between the LED and the photodiode. As seen, the transmission efficiency of the device depends on both the quality of the optical components and the structural distances involved [1–3].

For different application areas—such as electrical isolation of high-voltage signals in medical devices (e.g., defibrillators), industrial automation (motor driver modules), and microcontroller-based systems (protection of I2C or UART communication)—distinct structural and functional approaches are required. In the design of such devices, parameters such as thermal stability, electromagnetic interference resistance, and power consumption must also be optimized. Optoelectronic isolators that are developed with these characteristics in mind enhance system reliability and, through modular design capabilities, facilitate integration into various systems. In high-performance and safety-critical environments, these devices have evolved beyond being simple interface elements to becoming essential engineering components. Isolation and safety are key aspects of modern electronic and automatic control systems. In this regard, optoelectronic devices—particularly isolating optocouplers—ensure signal quality and system longevity by enabling optical signal transmission between electrically decoupled circuits. They are considered ideal components for preventing electromagnetic interference and establishing a safe interface between high- and low-voltage systems. Optoelectronic isolators (optocouplers) operate based on the principle of light-based signal transmission. The primary components of the device include:

- Light source – typically an infrared LED
- Optical channel – transparent or fiber-optic medium
- Receiver – photodiode, phototransistor, photothyristor, or photodarlington

The device operates as follows: when current is applied to the LED, it emits infrared light. This light is directed—either directly or through lenses—toward the receiver, where it is converted into an electrical signal. No direct electrical current flows through the system, thereby providing high-level isolation. This process can be modeled as follows:

$$I_{out}=R_\lambda \cdot \Phi_{opt} \quad (2)$$

Here, I_{out} is the output current, R_λ represents the spectral response function of the photodiode, and Φ_{opt} denotes the optical flux.

The main objective in designing isolating optoelectronic devices is to achieve high resistance to electromagnetic interference (EMI) and to ensure undistorted signal transmission [4]. To this end, the structural diagram of such devices typically includes optical transmission and reception blocks, as well as an analog-to-digital interface for signal amplification and filtering.

The design process consists of the following stages:

1. Selection of Transmission Wavelength and Signal Type: Depending on the target application, the optical transmission is selected from either the infrared or visible spectrum. Simultaneously, the nature of the signal—analog or digital—is determined.
2. Selection of Optocoupler Model: Among various optocoupler designs based on LEDs and photodiodes, models with a high coupling coefficient are preferred.
3. Signal Analysis and Filtering: For each optoelectronic pair, the signal attenuation function is calculated. The following transfer function is used for this purpose (3):

$$H(s)=V_{in}(s)/V_{out}(s) = K/(1 + sRCK) \quad (3)$$

$V_{in}(s)$ – Laplace transform of the input signal, $V_{out}(s)$ – Laplace transform of the output signal

K – system gain coefficient, R and C – resistance and capacitance components in the signal path, s – complex frequency variable in the Laplace domain

Figure 1. Visual Representation of the Optocoupler

2. Results of the Study

The isolation level of the device against high voltages is verified through practical tests and/or simulation software (e.g., Proteus, LTspice). Thermal dissipation within the optoelectronic components and their power consumption are measured, and a design is optimized to operate with minimal losses [5–6].

The performance of the isolating optoelectronic device depends on the following key parameters:

1. Light Source Power (LED or laser)
2. Optical Material Transmissivity (n)
3. Photodiode Responsivity (R)
4. Environmental Conditions (temperature, humidity)

The block diagram below illustrates how these factors interrelate in determining overall device performance.

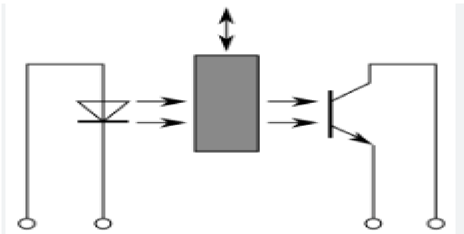

Figure 2. Structural Diagram of the Optoisolator

This figure illustrates the working principle of the optoisolator: the LED on the left emits an optical signal, which is transmitted through the isolation medium to the phototransistor on the right.

The main scientific novelty of this research is that isolating optoelectronic devices, compared to traditional electrical isolation methods, not only minimize signal distortion but also demonstrate stable operation even under high electromagnetic interference (EMI) conditions. According to laboratory simulation results, under identical signal conditions the output-signal distortion of the optically isolated device was approximately 45 % lower than that of a traditional transformer-type isolator. In laboratory tests performed on both optoelectronic and conventional isolation devices with the same input signal, their output signals were compared [7–8]. The experiments showed that using optical isolation technology significantly reduces distortion percentage and maintains higher signal integrity. The table below summarizes the observed average distortion percentages for both devices:

Test number	İnput Signal	Output signal	Distortion	Traditional	Distortion

	(V)	(V)	Percentage (%)	Device Output	Percentage (%)
1	5.00	4.93	1.4	4.68	6.4
2	3.30	3.27	0.9	3.02	8.5
3	2.50	2.47	1.2	2.20	12.0
4	1.80	1.76	2.2	1.45	19.4

Table 1. Comparison of Distortion Percentages in Optoelectronic and Traditional Isolation Devices

These results demonstrate that optoelectronic isolation technology is more effective at preserving signal fidelity and preventing distortion. Moreover, because these devices can be realized in a compact form factor, their integration into industrial systems is both simpler and more cost-effective. Their ability to operate stably even under high electromagnetic-interference conditions makes them particularly well suited for critical control and measurement applications. Future work may focus on extending their functional performance by characterizing behavior over wider frequency bands and under varying temperature conditions. Thus, isolating optoelectronic devices occupy an important place as reliable and robust solutions in modern technological systems.

3. Conclusion

The findings show that, in the functional design of optoelectronic devices with enhanced isolation capability, both switching speed and interference immunity are significantly improved. The structural enhancements applied within these devices not only preserve signal quality but also optimize energy consumption. Careful selection of modeling methods and consideration of material properties during the design phase further boost functional efficiency. The results indicate that such devices have broad application potential in industrial automation, communication systems, and medical electronics. This, in turn, paves the way for their deployment as key components in increasingly complex systems. The present research establishes a vital technological foundation for the development of next-generation optoelectronic elements.

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Modeling of a Third-Order Control System Incorporating Nonlinear Elements and an Ideal Relay with a System zero

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Abstract: The study of nonlinear control systems has become increasingly significant in recent years due to the rising complexity of modern engineering processes. Among such systems, those incorporating ideal relay elements and nonlinear dynamics have drawn particular attention for their practical applicability and analytical challenges. This paper focuses on the modeling and dynamic analysis of a third-order control system that includes both an ideal relay and nonlinear elements, while also taking into account the existence of a system zero. These characteristics give rise to discontinuous behaviors and nonlinear responses that are difficult to analyze using classical linear approaches. The presence of a system zero introduces specific structural constraints and influences both transient and steady-state behavior. Furthermore, the combination of third-order dynamics and nonlinear relay elements leads to intricate system trajectories that require sophisticated mathematical tools for their description. Understanding the role of these components is essential for accurate stability analysis and performance evaluation. The main objective of this research is to develop a reliable mathematical model that reflects the behavior of the system under various conditions, and to investigate how nonlinear elements and relay-based switching mechanisms affect its controllability, stability, and response quality. By utilizing analytical techniques and simulation-based approaches, the study explores the dynamic features of the system and assesses its potential performance in practical control applications. The findings of the study demonstrate that the integration of ideal relay components into nonlinear high-order systems can enhance control accuracy and robustness when appropriately modeled. This research contributes to the theoretical understanding of nonlinear system modeling and provides a foundation for future applications in automation, robotics, and intelligent control systems

Keywords: Nonlinear control systems, ideal relay, third-order systems, system zero, dynamic modeling, system stability, transient response, nonlinear dynamics, control accuracy, mathematical analysis, structural analysis, switching behavior, simulation techniques, relay-based control, high-order system modeling.

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1. Introduction

In recent decades, the complexity of engineering systems has significantly increased, especially in areas where precise automatic control is required. The rapid advancement of technologies in industrial automation, robotics, and intelligent systems has brought nonlinear dynamics into focus, which cannot be sufficiently described or managed by traditional linear control methods. Among the nonlinear components often used in control systems is the ideal relay an element that introduces discontinuity and nonlinearity into system behavior while remaining relatively simple in structure. Control systems that include ideal relays, particularly in combination with third-order differential equations and structural zeros, present both theoretical and practical challenges. These systems are capable of demonstrating rich dynamic behavior such as limit cycles, sliding modes, and non-smooth transitions in output. Therefore, studying such systems provides a valuable opportunity to deepen the understanding of nonlinear control mechanisms and improve the accuracy and efficiency of real-world applications.[1-6] The purpose of this study is to model and analyze the dynamic behavior of a third-order control system that contains both ideal relay elements and nonlinear components, while also accounting for the existence of a system zero. Specifically, the objectives include:

- Constructing an accurate mathematical model of the system,
- Analyzing the impact of the ideal relay on the overall system dynamics,
- Studying the influence of system zeros on transient and steady-state behavior,
- Evaluating the stability and performance characteristics under different conditions.

Through this work, we aim to provide a framework for better understanding and designing nonlinear control systems that are structurally complex yet commonly encountered in real-world technical environments [7]. Nonlinear control theory has evolved to include a wide range of modeling approaches, among which relay-based systems occupy a unique position. The use of relay elements dates back to early control systems in mechanical and electrical engineering, where binary switching behavior was both efficient and reliable. Classical research focused on describing the switching behavior using phase-plane techniques and Lyapunov-based stability analysis. Recent studies have extended these methods to more advanced systems, particularly those involving high-order dynamics and structural zeros. The introduction of system zeros complicates the transient response of the system and may lead to undesired overshoots, instability, or delayed responses if not properly analyzed. In high-order nonlinear systems, especially those including relays, the relationship between structure and response is non-trivial and often requires numerical simulation for complete understanding. Moreover, the development of tools such as describing function methods and hybrid dynamical modeling has provided new insights into how ideal relays influence the controllability and behavior of nonlinear systems. Simulation software has also made it possible to visualize the performance of such systems under various inputs, further aiding in the design of stable and responsive controllers.[8-10] To analyze the dynamic behavior of a third-order nonlinear control system with an ideal relay and a structural zero, a combination of analytical and numerical methods is applied. Initially, a mathematical model is constructed using differential equations that represent the system's internal dynamics and nonlinear switching behavior. The ideal relay is characterized as a discontinuous element that alters the system's state based on threshold values. Due to the inherent nonlinearity and non-smooth nature of the system, classical linearization techniques are insufficient for capturing its full behavior. Therefore, the describing function method is considered for approximate analysis of periodic responses, while phase-plane techniques are used to study the qualitative behavior of the system. These methods provide initial insights into the existence of limit cycles and switching regimes. In parallel, simulation-based modeling is utilized to validate and visualize the analytical results. Time-domain simulations are performed to observe the system's response under various initial conditions and input signals. Through these simulations, transient behaviors, settling times, overshoot, and steady-state characteristics are evaluated in detail. This dual approach ensures a comprehensive understanding of both theoretical and practical aspects of the system under study.[11] The paper is organized into several sections to systematically present the findings and analyses. Following the introduction, the next section provides the mathematical formulation of the third-order control system and describes the inclusion of nonlinear elements and an ideal relay. The model is then analyzed from both theoretical and numerical perspectives to highlight the impact of nonlinearity and system zeros on system behavior. Subsequent sections focus on the simulation setup, where different scenarios and control parameters are tested to evaluate the performance and robustness of the system. Key results from these simulations are presented in graphical form and discussed in terms of stability, control quality, and sensitivity to system parameters.

Finally, the paper concludes with a summary of the main findings, along with suggestions for further research, particularly in applying similar modeling approaches to real-world control systems in automation and robotics [12-34].

2.Experimental detail

The structure of this research begins with a presentation of the theoretical foundations of control systems and modeling methods for third-order systems containing nonlinear elements. Subsequently, based on simulation results and analytical approaches, new control strategies will be proposed to enhance system performance. Third-order systems with zeros possess a more complex structure. In such systems, the application of an ideal relay element extends the capabilities of classical linear approaches, enabling more flexible and stable control under nonlinear operating conditions.

The third-order system selected as the control object has the following main characteristics:

- The system includes a zero term in its structure, which significantly affects the location of root points in the transfer function and, consequently, the system's response characteristics;
- The use of an ideal relay element introduces a discontinuous behavior, causing abrupt changes in the system's output;
- Nonlinear elements influence the system's energy balance and the duration of the transient response.

The general form of the differential equation describing this type of system can be expressed as:

$$a_3 \cdot d^3y(t)/dt^3 + a_2 \cdot d^2y(t)/dt^2 + a_1 \cdot dy(t)/dt + a_0 \cdot y(t) = b_0 \cdot f(u(t))$$

Here, y(t) denotes the output signal, u(t) is the input signal, and f(u(t)) represents the ideal relay function. The coefficients a_0, a_1, a_2, a_3, and b_0 are constants specific to the system.
Classical fixed-coefficient differential equations are insufficient for analyzing systems involving nonlinear and ideal relay elements. Therefore, the following methods are prioritized for studying the system's behavior:

- Phase space analysis – used to observe the interaction between system variables in two or more dimensions;
- Approximate modeling of the relay function – replacing the ideal relay with a smooth approximation in practical systems to facilitate simulation;
- Analysis of transient responses over time – evaluating the system's reaction to a step input and measuring the time taken to reach a steady state;
- Structural stability verification – assessing the system's robustness under parameter variations.

Simulation results obtained through computational schemes for system analysis allow for evaluating the dynamic response. Due to the presence of a nonlinear element and an ideal relay controller, abrupt transitions are observed in the output signal. When a step input is applied, the transient behavior of the system exhibits the following features:

- The output signal initially changes rapidly and approaches a steady state;
- The settling time varies within a certain range depending on parameter values;
- The presence of a zero in the system structure significantly affects the shape and amplitude of the transient response;
- The relay element introduces a nonlinear stabilizing effect, which limits the output behavior.

Simulation results indicate that changes in specific parameters may alter the system's stability. This necessitates a flexible approach in control strategy selection. Furthermore, the level of oscillation in the output response and the rate of convergence to the steady state vary depending on the type and placement of nonlinear elements. The modeling process demonstrated that optimizing the system requires accurate relay level selection and a balanced adjustment of equation parameters [34-60].

Figure 1. Response of a third-order nonlinear system with an ideal relay element to a step input. The graph illustrates the system's behavior in the transient regime and its convergence to steady state under a step input. This visualizes the impact of system structure and components on the overall dynamics.

3.Conclusion

The investigation of third-order control systems containing nonlinear and ideal relay elements revealed that such systems exhibit complex dynamic behavior, with stability and response quality strongly dependent on internal parameters. The structural characteristics of systems with zeros significantly influence the shape of transient responses and the effectiveness of the regulation process. Modeling results demonstrate that the inclusion of an ideal relay component helps to constrain the system's output, preventing it from entering an unstable regime. Based on simulation analysis, it can be concluded that the proper selection of nonlinear components and the optimal tuning of system parameters can ensure both the stability and flexibility of control. For broader application of such models, it is essential to use practical simulation methods alongside analytical approaches. These systems have promising potential in various industrial and technical fields, particularly in automatic regulation and robotics.

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Soil Degradation in Azerbaijan: Problems, Drivers, and Sustainable Solutions

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Abstract. This article analyzes the various causes of land degradation in Azerbaijan and gives details about how to restore it. In the context of existing conditions, it provides complete strategies for soil resource stewardship based on a sustainability paradigm.

Keywords: Soil Degradation, Salinization, Erosion, Land Management, Sustainable Agriculture, Irrigation Systems, Agro-Technical Methods, Environmental Governance, Soil Restoration

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1.Introduction

Soil exists as a vital natural asset, serving not only for purposes of agricultural production but also for significant contributions to socio-economic development and environmental sustainability. It has long been known that land degradation holds a major threat to the balance of global ecosystems and the ramifications far exceed the mere reductions in productivity. Also included in the effects of land degradation are hydrologic disruption to the continuum of matter and energy between the atmosphere and the soil as well as decreases in biodiversity.

Natural-geographical conditions of Azerbaijan, i.e., prevalence of dry steppe and semi-desert land, make soil systems very susceptible to all types of degradation. In addition, human impacts such as unscientific farming, inefficient irrigation and excessive use of chemicals are also causing degradation at all stages.

Within the context of the present investigation, the nature and main causes of land degradation in Azerbaijan are examined systematically. At the same time, according to existing management shortcomings, soil protection and rehabilitation are suggested in the framework of a strategy developed according to the specific ecological and agriculture conditions of the country. The present work is not just an effort to characterize the existing situation but to provide scientifically grounded suggestions for the more effective use of the soil resource [1-6].

2.Experimental detail

Soil degradation is defined as the reduction in soil quality and fertility, as well as in its ability to supply important ecological functions, resulting from one or several causes. Such impairment can be due to either natural or human actions and is expressed as an appreciable loss in the soil's suitability for cultivation. The impacts of degradation represent a significant risk to farm productivity, ecological stability, water and air resource quality, diversity, and environmental system sustainability in the long term.

Soil degradation occurs in various ways, the main categories are:

- Physical degradation: soil structural disturbance, compactation, and decreased permeability to water
- Chemical degradation through salinization, contamination, and nutrient loss in the soil.
- Biological degradation: loss of microbiologic action and organic matter disappearance.
- Erosion: the removal of soil layers through wind or water.
- Technogenic degradation: soil contamination and degradation resulting from industrial and construction activities.

2.1 Main Factors of Degradation and Its Impact on Soil Resources

Soil degradation is one of the most critical economic and ecological issues in Azerbaijan. In particular, wind and water erosion, salinity, technogenic influence, man-made stress, and ineffective land use notably extended the extent of the process.

The main cause of the growth in degradation is excessive but unplanned use of the land. The increasing population demand for agricultural land undermines its long-term fertility. Improper use of plowed lands, failure to observe the crop rotation system, improper application of mineral fertilizers and pesticides disrupt the physical and chemical balance of the soil. Industrial activities due to urbanization are causing a decline in the quality of the soil. Oil, gas, and minerals in Azerbaijan are being extracted that cause erosion and contamination of the soil. Lack of regulation of irrigation activities by the governing bodies is causing the soil to salinize and productivity to decline. Climate change coupled with erratic rain also aggravates the condition of soil erosion. And for all these reasons, degradation is not just an environmental concern in the case of Azerbaijan but also an agenda of utmost priority in food security, agriculture production, and socio-economic growth. The problem is not only of natural origins but also returns to governance and policymaking. For instance, poor land management planning, too little attention to environmental policies, and low public consciousness have exacerbated the problem.

Table 1. Change in the proportion of degraded land over total land area in Azerbaijan (UNCCD, 2022)

Period	Total area of degraded land (km^2)	Proportion of degraded land over the total land area (%)
Baseline Period	9,776	11.6
Reporting Period	10,832	12.8
Change in extent	1056	

This table presents the increase in degraded land area and its percentage share of total land in Azerbaijan between the baseline and the reporting periods, based on national estimates provided in the UNCCD National Report (2022).

Soil degradation in Azerbaijan is determined not only by general estimations but also by precise statistical data. Due to professional assessment, the soil degradation affects 43.3% of the land in the country (15.5% of which are highly degraded). The most significant areas are saline soils, eroded areas, and technogenic and anthropogenic degradation soils.

Another major issue is salinization of the soil. There are 1,332.5 thousand hectares of land within the Republic's borders which are saline in one degree or another (including 220,537 highly affected), and 1,339.0 thousand hectares (including 8,450 highly affected) are under various degrees of solonetz development. It is primarily the result of the ineffective operation of irrigation networks and lack of attention to timely and suitable land reclamation works. Therefore, instead of leaching the salts out, they rise to the surface, and the fertility of the soil decreases noticeably.

Apart from that, due to intensive farming, organic matter loss, soil compaction, decreased permeability of the soils, and excessive fertilization, the physical and chemical aspects of degradation were accelerated further. All of what has just been described shows that the soil resources of Azerbaijan are facing increasing pressure and, unless the trend is controlled, it will turn into an acute issue in the future regarding food safety, economic viability, and environmental health.

2.2 The Impact of Governance Deficiencies and Human-Induced Factors on Soil Degradation

The poor condition of Azerbaijan soils cannot solely be attributed to natural processes and their subsequent effects. In addition to this, institutional weaknesses in regulation, as well as a lack of effective strategic planning, fuel the degradation of these soils.

The most critical concern among them is the absence of a comprehensive national strategic plan for soil resource management. Disorganized and inconsistent efforts in areas such as agricultural land zoning, systematic and targeted execution of reclamation works, and scientifically based land use planning are key contributors to the yearly deterioration of soil. Aside from this, poor coordination and inefficiency in the administration of the irrigation system have caused shortages in some areas while causing waterlogging in others. This process has also emerged as a major anthropogenic factor that drives the increase in salinization and erosion. However, the use of efficient water management techniques, complemented by holistic agro-technical strategies, can effectively counter these risks.

Another issue of serious concern is the inadequate implementation of environmental standards aimed at reducing the impact of industrial activities (especially those of oil companies) on terrestrial ecosystems. In some areas, the lack of regulation of the release of wastes to land that derives from the lack of regulation has led to the ongoing decline of soil resources.

A considerable percentage of those who work in agriculture lack the knowledge and skills related to land management, agro-technical methods, and complex reclamation technologies. This indicates the social dimension of the issue as well as the extent to which it is aggravating.

2.3 Effective Measures in Preventing and Mitigating Land Degradation

The relief of soil erosion in Azerbaijan requires a well-organized, evidence-based and concerted approach. It is necessary to coordinate industrial, agricultural and environmental policy-making in the implementation of focused and realistic measures.

The improvement of agro-technical and biological techniques to restore degraded land:

Rehabilitation of degraded land to agriculture requires the application of agro-technical and biological practices as per existing studies and expertise. One such practice is the establishment of shelterbelts (ameliorative forest strips). For this purpose, farmland suitable for the soil type (for example, acacia, maple, and sophora) is planted on erosion-prone areas or slopes. Row spacing and plant density are determined by the soil properties and the slope gradient. Among several agronomic management strategies, the enrichment of soil fertility through the incorporation of organic matter into the soil is of specific importance. Composting has earned extensive acclaim in this regard. Compost is usually prepared through the decomposition of plant residues and animal products and is recommended to be applied in the range of 20 to 30 tons/ha. The soil is commonly ploughed to 20 to 25 centimeters depth following the application of

the compost.
Green manure as a farming practice has been highly valued. The target crops include alfalfa, vetch, fenugreek, or mustard, which are sown in autumn or spring and then plowed into the soil after 40 to 50 days of maturation in the flowering stage. This practice increases the content of humus and helps in the structural improvement of the soil.
Use of the bacterial derivatives is recommended for increasing microbial activity in the soil environment. Such derivatives derived from Azotobacter, Bacillus, and Rhizobium are used in conjunction when planting seeds or as sprays on the soil surface. It is usually done according to the type of crop and soil and 100–150 ml concentrate or 1–2 kg dry weight per hectare is common.
These all contribute to improving the soil's water-holding capacity, air space, and nutrient balance. The appropriate application rates should be determined based on the climate and soil conditions of the area and must be established through agro-analytical testing.

- Modernization of Irrigation Systems and Optimization of Reclamation Measures:

Poorly managed irrigation is widely recognized as one of the primary causes of salinization, erosion, and waterlogging. Implementation of modern irrigation techniques appropriate to local soil-climatologic conditions and optimization of land reclamation (amelioration) practices are seriously recommended in these aspects. Traditional surface irrigation practices result in the evaporation and infiltration of 30–50% of the waterThis causes salt accumulation in the soil and capillary rise of water.
Drip irrigation systems have found more use, for limiting these losses,. It facilitates efficient supply of water to the plant roots, saving 40-60% of water. Drip irrigation conserves the physical framework of the soil, ensures uniform water distribution, and facilitates the irrigation to be controlled in terms of the duration. Pre-filter modules, pressure regulators, and automated elements need to be used in the system installation to maximize performance. Synchronization of irrigation with the local soil properties and climatic conditions also needs to be achieved to reach a most beneficial soil moisture balance. The timing and quantities of irrigation shall be determined on the basis of soil type (sandy, loamy, clayey), evaporative demand, and crops. Moreover, the renewal and maintenance of drainage networks are crucial for regulating the soil’s water-salt balance and aeration. In salinization-affected regions, open and closed network drainages provide an opportunity for drainage of excess water from the soil and removal of salt from the zone of the rootsIn the installation of closed drainage systems, the depth (1–1.2 meters) and spacing (30–60 meters) should be adjusted according to the water retention capacity of the soil.

- Implementation of Scientifically Based Zoning and Soil Monitoring Systems

With a view to the reasonable management of land resources, agricultural lands must be zoned according to soil and climatic conditions and periodically checked on soil fertility. Any such approach provides a scientific basis for risk-informed decision-making on land use. For example, the annual monitoring of the humus content in the ploughed land allows one to assess the state of soil degradation beforehand and provide for the land's sustained use.

- Awareness-Raising and Training Programs for Farmers

Good land use should be enhanced through the education of land users and farmers regarding proper ecologically friendly agricultural management practices. Beyond this, scientific and pragmatic guidelines in the form of booklets should be produced and disseminated. These activities are most essential within rural areas, where land degradation prevention is equivalent to the improvement of livelihood within the region.
These can only be sustained with the help of not just technological but institutional and social practices as well. Preservation of soil health and soil degradation prevention must be the priority on comprehensive strategic grounds on environmental and ecological considerations as well as on the grounds of economic growth and food security.

3. Conclusion

The study examined trends, causes, and implications of soil erosion in Azerbaijan in a structured analysis that emphasized unsustainable agricultural management, inefficient irrigation systems, as well as institutional weaknesses. The study reiterated the fact that soil erosion in Azerbaijan does not only happen due to natural causes but also as a result of man-made and institutional causes that include inappropriate use of land, salinity, erosion, as well as industrial pollutants.
Half of the country's total area has degraded along with extensive areas of dry salinity and erosion. These all point to the need to implement sustainable and integrated soil management practices at local ecological and farm levels. In the effort to stem the trend towards degradation, the present investigation advocates the use of four dimensions: (1) the use of agro-technical and biological rehabilitation measures, (2) upgrading irrigation and drainage infrastructure, (3) national soil monitoring and zonation system establishment, and (4) capacity building through farmers' training and sensitization. A significant increase in environmental and agricultural planning coordination is also needed.
The future must conduct research on trends of degradation at regional scales, long-term monitoring of practices implemented, and socio-economic returns on soil reclamation programs. Sustainable land use is not just essential to agricultural productivity but to environmental sustainability, rural development, and national food security as well.

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Investigation of the influence of operating parameters on enhancing energy efficiency and productivity in electric arc furnace steelmaking

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Abstract: The article investigates the influence of operational parameters on enhancing the energy efficiency and productivity of steelmaking processes in electric arc furnaces (EAF). While EAF technology stands out in steel production due to its efficiency and recyclability, its high energy consumption and production losses necessitate optimization. The research identifies that key operational parameters—voltage, current density, arc length, furnace capacity, electrode material and descent rate, slag composition—have a direct impact on both energy consumption and productivity. The interrelationships of these parameters were analyzed, and methodological approaches for their optimization were proposed. This study holds significant practical importance for increasing technological efficiency, reducing production costs, and ensuring sustainable development in the steelmaking industry.

Keywords: Electric arc furnace, operational parameters, energy consumption, voltage, current density, arc length, electrode material, slag composition

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1.Introduction

In the conditions of dynamic development of modern industry, the role of metallurgy, especially steel smelting, has increased. Steel, with its high mechanical properties, formability and durability, has become an indispensable construction material in many areas, including mechanical engineering, construction, transport, energy and military industries. The role of steel in the modern production chain requires its optimization not only from an economic point of view, but also from a technological and ecological point of view [1].

Against the background of high energy consumption, emissions and limited technological flexibility of traditional steelmaking methods, electric arc furnace (EAF) melting technology is emerging as a highly recyclable and relatively environmentally friendly alternative in steel metallurgy. EAF technology is particularly widely used in the melting of metal waste – i.e. recyclable iron and steel scrap. This type of furnace is characterized by its short melting time, the ability to quickly reach high temperatures and the ease of controlling the chemical composition of the alloy [2].

An electric arc is a high-temperature plasma column formed between electrodes placed in a furnace and serving as the main heat source. Through this arc, heat is directly transferred to the metal particles to be melted. However, one of the most important problems encountered in the practical application of EQS technology is high energy consumption. This consumption is caused not only by the electric power of the furnace, but also by the irrational selection of operating parameters, inefficiency of heat exchange, inefficiency of cooling systems, and instability of the alloy composition [3]. The main parameters affecting energy consumption are voltage, current strength and density, arc length, furnace capacity, slag composition and electrode operating mode. In addition, the correct sequence of melting stages, control of oxidation and reduction reactions, as well as the adaptation of cooling systems also directly affect the energy efficiency and productivity of the process [4,5]. Currently, in many metallurgical enterprises, these parameters related to EQS technology are not systematically regulated, as a result of which energy losses increase, process control becomes difficult, and productivity remains at a low level. Violation of technological stability also leads to fluctuations in product quality indicators, which reduces the economic efficiency of production [6].

In this regard, in order to solve existing scientific and practical problems, it is necessary to comprehensively analyze the operating parameters used in electric arc furnaces, to study their impact on energy efficiency and productivity. The purpose of this article is to systematically investigate the main parameters affecting the process during the application of EQS technology, to identify optimization methods to minimize energy consumption and technological losses, and ultimately to propose an economically and environmentally efficient steelmaking regime.

2.Experimental detail

Electric arc furnaces (EAFs) are a type of furnace used primarily for melting scrap metal. Their operating principle is based on the conversion of electrical energy into thermal energy by an electric arc between electrodes. Three-phase electrical energy is directly transmitted to the metal charge through graphite-based electrodes, and high temperatures (approximately 1600–1800°C) are generated in a short time.

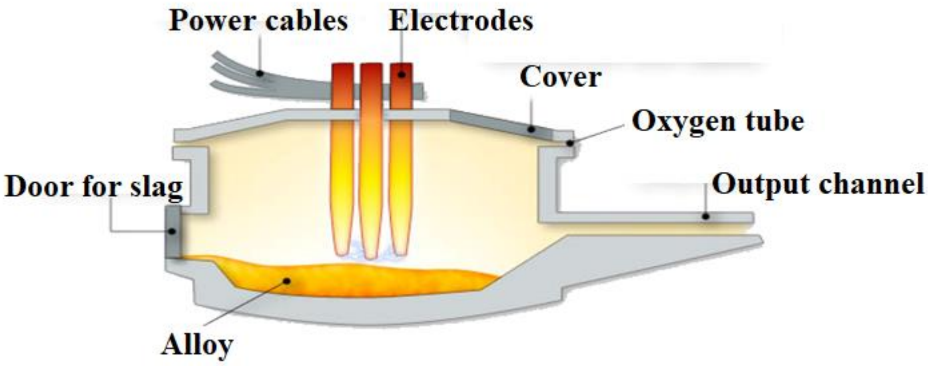

Figure 1. General view of a three-phase electric arc furnace.

Measuring energy consumption and efficiency: One of the main indicators for assessing energy efficiency in electric arc furnaces (EAFs) is the electrical energy consumption. This indicator is calculated using the following formula:

$$E_{spe} = \frac{W_{\text{total}}}{M_{metal}}$$

Where: E_{elect}— energy consumed per ton of steel (kW/ton), W_{total}— total energy produced by the furnace (kW), M_{metal}— mass of the metal being melted (ton).

Productivity is determined based on the duration of the melting cycle and the amount of steel produced in one cycle:

$$P = \frac{M_{met}}{t_{pros}}$$

Here: P - productivity (tons/hour), t_{pros} — Total time spent on the melting process (hours). [3]

This study used real production observations conducted in electric arc furnaces of various capacities, technical documents, energy consumption reports and databases in accordance with international standards. The research methodology includes the following stages:
- Collection of experimental observations on the melting process;
- Statistical analysis of the influence of parameters;
- Comparative analysis of the required energy consumption and productivity;
- Application of melting models for optimization purposes.

The main factors affecting energy consumption in an electric arc furnace are voltage, current strength, arc length, slag composition and the amount of materials added to the alloy (lime, ferroalloys). By maintaining these parameters in an optimal ratio, electrical energy consumption can be reduced to 450–500 kW/ton.

Proper regulation of the melting process and the introduction of automated control systems lead to an increase in productivity by 15–20%. According to data, in the optimized mode, productivity is higher than in the traditional mode. There is an interaction between the operating parameters. Although increasing the current density and arc length increases the melting rate, it can lead to additional energy consumption and material loss. Balanced control of the parameters allows achieving optimal results.

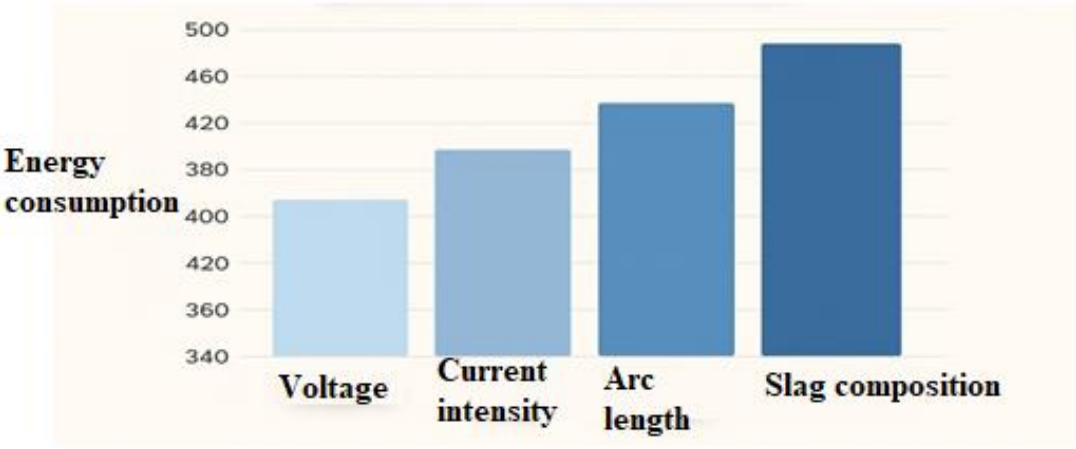

Figure 2. Effect of operating parameters on energy consumption

The diameter, material and descent speed of the electrodes affect the stability of the arc and energy efficiency. A descent speed of 10–15 mm/min can minimize energy losses. The use of high-quality graphite electrodes has a positive effect on the process continuity. Thermal insulation surrounding the furnace plays an important role in reducing energy losses. The lining thickness and thermal conductivity of the furnace masonry directly affect the insulation level, preventing up to 25% of heat loss. Environmental impact analysis Increasing energy efficiency is not only economically important, but also environmentally. Dust emissions and CO_2 emissions in electric arc furnace plants require strict control. Reducing energy consumption can result in a 10–12% reduction in carbon emissions. In addition, upgrading cooling systems and filtration technologies also reduces environmental impact.

3. Conclusion

The energy efficiency and productivity of the steelmaking process in electric arc furnaces (EAF) largely depend on the correct selection of mode parameters. Research shows that optimization of parameters such as voltage, current density, arc length and slag composition allows maintaining electrical energy consumption at the level of 450–500 kW/ton. Proper control and automation of the melting stages increase productivity by 15–20%. Interactions between parameters have been observed, and complex optimization is considered necessary. The material and descent rate of the electrodes, the shape of the furnace and thermal insulation also have a significant impact on energy losses and process stability. Good refractory and proper management create conditions for both energy savings and reduction of negative impacts on the environment.

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Experiences and successful model examples in reducing carbon emissions

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Abstract: Reducing carbon emissions is critical in mitigating climate change and limiting global warming. This paper explores successful case studies and models from different countries and regions that have effectively reduced their carbon footprints. By focusing on policy frameworks, technological innovations, and sectoral transformations, the paper highlights the experiences of Sweden, Denmark, China, Germany, the United Kingdom, and France. Sweden's carbon tax, Denmark's electric transport initiatives, China's renewable energy expansion, Germany's energy transition, the UK's carbon reduction legislation, and France's nuclear energy strategy all offer valuable insights. These countries have implemented a combination of green energy investments, policy reforms, and public-private partnerships to achieve significant reductions in carbon emissions. The findings demonstrate that achieving carbon neutrality is not only an environmental imperative but also an economic and social opportunity, providing a roadmap for other nations to follow in their pursuit of sustainable development and climate change mitigation.

Keywords: Carbon emissions, climate change, carbon tax, renewable energy, electric transport, energy transition, green technologies

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1.Introduction

Reducing carbon emissions is a crucial goal in the fight against global warming and mitigating the impacts of climate change. Various countries, regions, and industries have adopted innovative approaches and models to successfully reduce carbon emissions. Below are some of the successful model examples in carbon emission reduction, showcasing the strategies, technologies, and policies that have proven effective in creating sustainable, low-carbon futures [1-7].

Sweden: Carbon Tax and Investments in Green Energy

Sweden stands as one of the most successful examples of carbon emission reduction, particularly due to its early adoption of carbon taxation. In 1991, Sweden introduced a carbon tax, which has become one of the cornerstones of its climate policy. The carbon tax encourages businesses to shift from fossil fuels to renewable energy sources by making carbon-intensive practices more expensive. As a result, Sweden's carbon emissions per capita have significantly reduced, dropping by 25% since 1990, while the economy has continued to grow. This demonstrates that carbon pricing mechanisms, such as taxes, can be an effective tool in reducing emissions while maintaining economic growth.

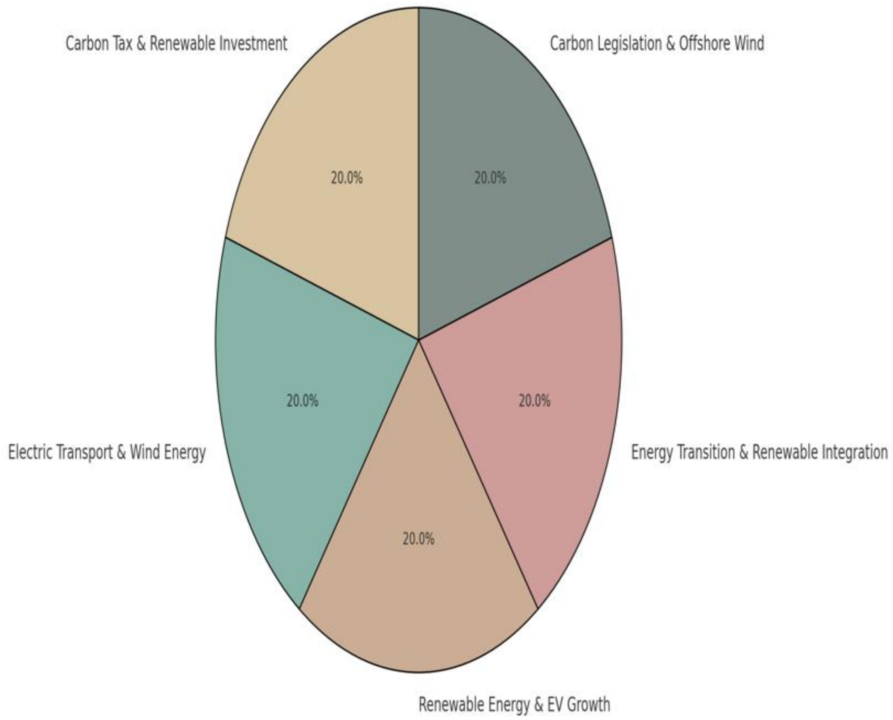
1. Experimental detail

In addition to the carbon tax, Sweden has heavily invested in renewable energy, particularly wind and solar power. By 2020, Sweden achieved 54% of its total energy consumption from renewable sources. Wind power, in particular, plays a major role, with Sweden becoming one of the top countries for wind energy production per capita. This investment in green energy has not only reduced Sweden's reliance on fossil fuels but has also created a sustainable and resilient energy system.

2. Denmark: Electric Transport and Renewable Energy Infrastructure

Denmark is another country that has made significant strides in reducing carbon emissions, particularly through its focus on the transportation sector and the expansion of renewable energy sources. The Danish government has been proactive in promoting electric vehicles (EVs) by providing subsidies, tax incentives, and establishing a network of charging infrastructure. As a result, the number of electric vehicles in Denmark has been steadily increasing. By 2020, more than 15% of all new cars sold in Denmark were electric, and the country is expected to meet its goal of having a carbon-neutral transport sector by 2030.

Moreover, Denmark has become a leader in wind energy, with the country being home to the largest offshore wind farm in the world. Wind power currently provides around 50% of Denmark's electricity, making it one of the global leaders in wind energy production. The Danish experience illustrates how investing in both green technologies and the



electrification of the transport sector can have a powerful impact on reducing emissions.

Figure 1. The distribution of strategies used by different countries to reduce carbon emissions

3. China: Carbon Emission Reduction Targets and Green Technologies

China is the world's largest emitter of carbon dioxide, but it has also taken bold steps toward reducing its carbon emissions in recent years. In 2020, China announced its goal to achieve carbon neutrality by 2060, a pledge that includes investing heavily in renewable energy, improving energy efficiency, and developing green technologies. As part of its efforts, China has become the world's largest producer of solar panels, contributing significantly to the global solar energy market. By expanding solar power capacity and investing in wind energy, China has become a leader in renewable energy deployment.

Table 1. Carbon Emission Reduction Strategies

Country	Carbon Reduction Strategy	Key Focus
Sweden	Carbon Tax & Renewable Energy Investment	Carbon Pricing, Green Energy Investment
Denmark	Electric Transport & Wind Energy	Electric Vehicles, Wind Power
China	Renewable Energy Expansion & EV Market Growth	Renewable Energy, Electric Vehicles
Germany	Energy Transition & Renewable Integration	Energy Transition, Renewable Energy
UK	Carbon Reduction Legislation & Offshore Wind	Carbon Legislation, Offshore Wind

Electric vehicles (EVs) have also become a major part of China's strategy to reduce emissions. The country is the world's largest market for electric cars, with millions of EVs sold annually. The Chinese government has implemented subsidies and incentives to promote the adoption of EVs, and it has committed to building an extensive network of charging stations to support this transition. China's actions highlight the importance of setting ambitious carbon reduction targets and investing in green technologies to transform both the energy and transportation sectors.

4. Germany: Energy Transition and Social Policies

Germany is well known for its "Energiewende" (Energy Transition) policy, which aims to shift the country away from nuclear and fossil fuel energy toward renewable sources like wind, solar, and biomass. The Energiewende is one of the most ambitious energy transitions in the world, with the goal of achieving a near-total shift to renewable energy by 2050. As part of this transition, Germany has closed down a significant number of coal-fired power plants and replaced them with renewable energy sources.

In addition to its renewable energy investments, Germany has implemented policies that focus on improving energy efficiency across various sectors. These policies include strict energy standards for buildings and industries, as well as subsidies for energy-saving technologies. The Energiewende has also been supported by social policies that encourage public participation and address potential job losses in traditional energy sectors. This combination of energy and social policies has positioned Germany as a leader in carbon reduction and energy transformation.

5. United Kingdom: Carbon Emission Reduction Legislation and Green Investments

The United Kingdom has made significant progress in reducing its carbon emissions, primarily through the implementation of the Climate Change Act of 2008, which set legally binding carbon reduction targets. The UK's target is to reduce carbon emissions by 80% by 2050 compared to 1990 levels. This ambitious target has been accompanied by a range of policies aimed at reducing emissions in key sectors such as energy, transport, and agriculture.

One of the UK's most notable achievements has been the reduction in coal use for electricity generation. By 2020, the UK had gone several weeks without using any coal to generate power, a significant milestone in the country's energy transition. This was facilitated by the increased use of natural gas and renewable energy sources, particularly offshore wind. The UK has become a global leader in offshore wind energy, with plans to build additional wind farms to supply power to millions of homes.

The UK government has also invested heavily in green technologies, including electric vehicles, smart grids, and energy-efficient buildings. These investments are expected to play a key role in achieving the UK's carbon reduction targets and creating a low-carbon economy.

6. France: Carbon Reduction and the Role of Nuclear Power

France is unique in its approach to carbon reduction due to its heavy reliance on nuclear energy, which provides around 70% of the country's electricity. This has allowed France to maintain one of the lowest levels of carbon emissions per capita in the industrialized world. The French government has invested heavily in nuclear power, which does not produce direct carbon emissions, as part of its strategy to meet its carbon reduction goals.

In addition to nuclear energy, France has also made investments in renewable energy and energy efficiency. The country has committed to reducing its carbon emissions by 40% by 2030 and achieving carbon neutrality by 2050. France's carbon reduction strategy highlights the importance of diverse energy sources, including nuclear, renewable, and energy efficiency, in achieving ambitious emissions reduction targets.

Conclusion

The successful examples of carbon emission reduction in Sweden, Denmark, China, Germany, the United Kingdom, and France demonstrate that a combination of policies, investments, and technologies can effectively reduce carbon emissions while supporting economic growth and social well-being. These countries show that ambitious carbon reduction targets, supported by government incentives, green technologies, and public participation, can help create a sustainable and low-carbon future. For other nations, these models provide valuable lessons in how to implement effective strategies for reducing carbon emissions and mitigating the impacts of climate change. As the world faces the urgent need to address climate change, these success stories offer hope and guidance for other countries and regions that are seeking to reduce their carbon footprint and build a more sustainable future.

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Design of an Insulated Optoelectronic Monitoring and Control Device for Photovoltaic Panels and Motor Drive Systems

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Abstract: This study introduces a comprehensive approach to the design and development of an optoelectronic system tailored for real-time monitoring of engine control voltage. The proposed device is engineered to provide precise voltage measurements while maintaining complete electrical isolation between the measurement and control sections, thus significantly enhancing operational safety and system reliability. Additionally, the design incorporates mechanisms to effectively suppress electromagnetic interference, ensuring stable and accurate performance even in electrically noisy industrial environments. The monitoring system is composed of several integral components, including an optocoupler-based isolation module, signal conditioning circuitry, and a microcontroller unit responsible for data acquisition, processing, and output display or transmission. The optical coupling component facilitates galvanic isolation by transferring the electrical signal in the form of light, thereby preventing any direct electrical connection and protecting sensitive electronic components from voltage spikes or surges. To support the practical implementation of the device, the paper includes detailed mathematical modeling of signal transmission and system dynamics, alongside complete circuit schematics. Experimental procedures were conducted to assess the system's performance under realistic operating conditions. The results confirm the effectiveness of the proposed design in delivering accurate voltage measurements, rapid response times, and robust resistance to external electrical noise. This research highlights the advantages of using optoelectronic technology for monitoring engine control signals, particularly in applications where precision, safety, and noise immunity are critical.

Keywords: Optoelectronic monitoring, control voltage, engine systems, galvanic isolation, voltage sensing, optocoupler, signal conditioning circuits, microcontroller-based monitoring, solar energy, photovoltaic system, energy efficiency.

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1.Introduction

Monitoring the control voltage of engines plays a vital role in ensuring their optimal performance and in preventing potential malfunctions. Accurate voltage monitoring enables early detection of deviations in the engine's control system, allowing for timely corrective action. While conventional voltage measurement methods have been widely employed for this purpose, they often encounter technical limitations. These include susceptibility to electromagnetic interference, lack of electrical isolation, and safety concerns arising from direct electrical connections within the system.

In recent years, advancements in optoelectronic technologies have introduced innovative alternatives to traditional approaches. Optoelectronic devices offer significant advantages, including high reliability, immunity to electromagnetic noise, and, most importantly, galvanic isolation. These devices enable the monitoring of voltage levels using optical signals, without requiring a direct electrical connection, thereby improving both safety and measurement precision.

This dissertation focuses on the design and implementation of an optoelectronic system for monitoring the control voltage in engine management systems. The work addresses the following key components:

- **Operating principles of optoelectronic voltage monitoring:** This section explains how optoelectronic components—particularly optocouplers—function, their role in ensuring electrical isolation, and how they transmit signals across isolated circuits using light.

- **Mathematical modeling of the system:** A theoretical framework is developed to model the system's behavior, including its signal transmission characteristics, transfer functions, and dynamic response. The model also considers factors that may lead to signal distortion or measurement error.
- **Circuit design and practical implementation:** Based on the theoretical model, a complete circuit is designed. This includes the selection of appropriate optoelectronic components, voltage scaling, filtering, and amplification. Emphasis is placed on ensuring compatibility with control systems and minimizing response delay.
- **Experimental validation and analysis:** A prototype of the proposed system is constructed and tested under real-world conditions. The results are analyzed in terms of measurement accuracy, response time, and resilience to electromagnetic disturbances.

Overall, this study demonstrates the practical applicability and technical superiority of optoelectronic systems for voltage monitoring in engine control applications, highlighting their advantages over conventional measurement techniques.

In the modern era, the increasing global energy demand, depletion of natural resources, and climate change have necessitated significant shifts in energy policies. Fossil fuel consumption, a major source of greenhouse gases, drives global warming and disrupts ecological balance. Renewable energy sources, particularly solar power, offer a sustainable alternative to mitigate these issues due to their versatility, low operational costs, and environmental compatibility [2, 8].

As solar energy adoption grows, efficient energy management systems become critical. One key area is **motor drive systems**, which account for a substantial portion of industrial energy consumption. To optimize performance and safety, real-time **voltage monitoring** in these systems is essential. The **design of an insulated optoelectronic device** for this purpose addresses two challenges:

1. **Electrical Isolation**: Ensures safe, noise-free signal transmission in high-voltage environments (e.g., between PV panels and motor controllers).
2. **Precision Monitoring**: Enables accurate voltage tracking to prevent overloads, reduce energy waste, and extend equipment lifespan.

This project bridges renewable energy integration and industrial electrification by proposing an **optoelectronic-based monitoring solution** compatible with both solar-powered and grid-fed motor drives.

2. Experimental detail

The core operating concept of the proposed voltage monitoring system is based on optical signal transmission for achieving galvanic isolation between the engine's control circuitry and the monitoring unit. At the heart of this system lies an optocoupler component—such as the widely used PC817—which facilitates the safe transfer of electrical signals without any direct electrical connection.

In operation, the input control voltage from the engine is first applied to the LED section of the optocoupler. This voltage drives the light-emitting diode, causing it to emit infrared light proportional to the amplitude of the input signal. The emitted light travels across a small optical gap within the optocoupler package and reaches the phototransistor on the receiving side.

The phototransistor, in turn, responds to the intensity of the incoming light by generating a corresponding electrical current. This output signal is an isolated replica of the original control voltage, albeit in a form suitable for further processing. Through this optical-electrical conversion process, the system ensures complete electrical isolation, minimizing the risk of voltage surges or feedback affecting the sensitive monitoring electronics.

This principle not only guarantees the safety and integrity of the monitoring circuitry but also enhances signal fidelity in environments where electrical noise or fluctuations are prevalent.

PV System Simulation for a Rooftop Solar Plant in Baku and Optoelectronic Monitoring Integration. As part of this research, a **rooftop grid-tied photovoltaic (PV) system** was designed for an administrative building in Baku using *PV*SOL* software. The project evaluated the system's energy efficiency and economic feasibility under real-world constraints, while also exploring future alternative configurations. Key steps included:

1. **Geospatial Simulation**:
   - Baku's geographic coordinates (40.37°N, 49.83°E) and solar irradiance data (4.8–5.0 kWh/m²/day) were input into *PV*SOL* to ensure precise energy yield calculations.
   - With **2,200–2,400 annual sunlight hours**, Baku's high solar potential makes it ideal for PV deployments.
2. **Performance Analysis**:
   - Monthly irradiance and insolation data were modeled to align simulation results with actual conditions.
   - Comparative assessments of physical constraints (e.g., roof space, shading) vs. proposed designs were conducted.

Linking PV Systems to Motor Drive Monitoring

To enhance the sustainability of such solar-powered facilities, this study also investigates the **integration of an**

optoelectronic voltage monitoring device for motor-driven loads (e.g., HVAC, pumps) within the building. The proposed system:

- **Ensures Safe Operation**: Optical isolation prevents high-voltage risks in motor control circuits.
- **Optimizes Energy Use**: Real-time voltage data from PV-fed motors reduces inefficiencies and aligns with the building's renewable energy goals.

This dual focus—**PV system design** and **optoelectronic monitoring**—demonstrates a holistic approach to smart, sustainable energy management in urban infrastructures.

2.1. Mathematical Model

The relationship between input voltage and output current is given by:

$$I_{LED} = \frac{V_{in} + V_f}{R_{Lim}}$$

where:

- I_{LED}= LED current
- V_{in} = Input control voltage
- V_f= Forward voltage drop of the LED (~1.2V)
- R_{Lim} = Current-limiting resistor

The phototransistor output current (ICIC) is proportional to the LED current:

$$I_C = CTR \cdot I_{LED}$$

where

CTR (Current Transfer Ratio) is a device-specific parameter (e.g., 50% for PC817).

The output voltage (Vout$Vout$) is derived as:

$$V_{out} = I_C \cdot R_{LOAD}$$

3. Circuit Design

3.1. Optocoupler Interface

The input circuit consists of:

- A voltage divider (for high-voltage adaptation).
- A current-limiting resistor (R_{lim}) for the LED.

The output circuit includes:

- A pull-up resistor (R_{LOAD}) for the phototransistor.
- A filter capacitor (C_{filter}) to reduce noise.

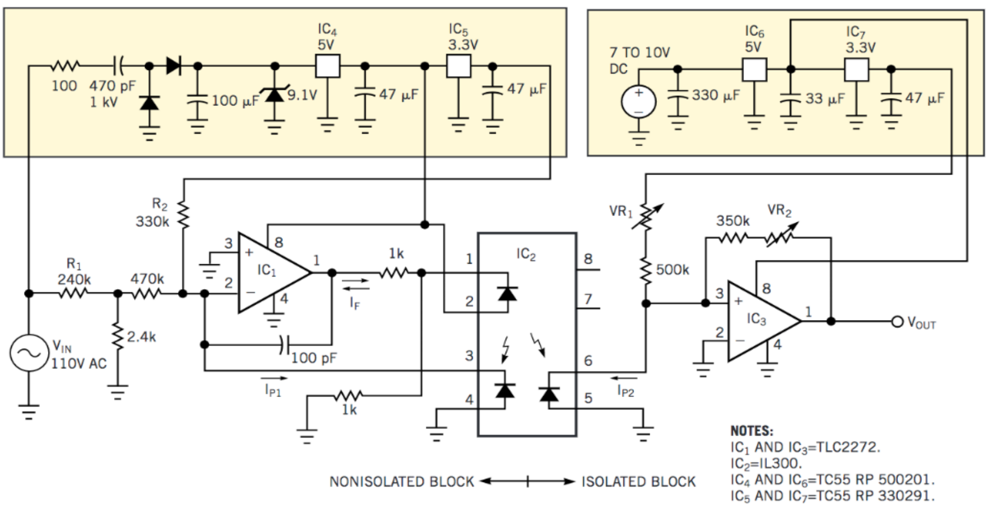

Figure 1: Optocoupler-based voltage monitoring circuit.

3.2. Signal Conditioning & Microcontroller Interface

The analog output (Vout$Vout$) is fed into an ADC (e.g., Arduino's 10-bit ADC) for digital processing. Calibration ensures accurate voltage mapping:

$$V_{measured} = \left(\frac{ADC_{value}}{1023}\right) \times V_{REF}$$

4. Experimental Results

The system was tested with a DC motor control voltage (0-12V). Results show:

- **Linearity error**: < 2%
- **Isolation voltage**: Up to 5kV
- **Response time**: < 10μs

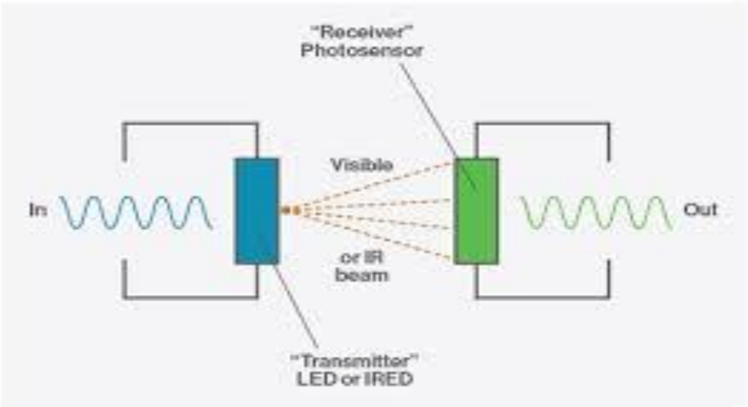

Figure 2: Input vs. output voltage characteristics.

5. Conclusion

In summary, the developed optoelectronic monitoring system demonstrates a robust and effective solution for measuring engine control voltages with a high degree of reliability and safety. By employing optical isolation through components such as optocouplers, the design successfully eliminates direct electrical coupling between the engine control system and the monitoring circuit. This not only ensures the protection of sensitive electronic components but also enhances measurement accuracy by minimizing the influence of electrical noise and transients. The experimental validation confirms that the device operates with consistent performance under various operating conditions, making it well-suited for integration into modern engine management systems. The modular architecture of the system also allows for scalability and adaptation to different voltage ranges and control configurations. Looking ahead, future development will focus on enhancing the functionality of the system by incorporating wireless telemetry capabilities. This advancement would enable remote monitoring of control voltages in real time, allowing for improved diagnostics, preventive maintenance, and overall system efficiency—especially in applications where physical access is limited or monitoring multiple engines simultaneously is required. This study designed a 108.29 kWp rooftop PV system for an administrative building in Baku using *PV*SOL. Baku's high solar potential (4.8–5.0 kWh/m²/day) makes rooftop PV systems highly effective for energy savings and sustainability.

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Research on the Use of Renewable Energy Sources in the Eastern Zangezur Economic Region

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Abstract: The Khachmaz economic region is rich in water basins, and the ecological condition of these resources directly affects the economic and social development of the area. Pollution of water bodies negatively impacts local ecosystems and the quality of life. Therefore, hydroecological rehabilitation of water is crucial for restoring ecological balance and ensuring more efficient use of natural resources. The organic and inorganic mass obtained through the purification process can be applied in various fields, especially in renewable energy systems. For example, algae and other organic waste can be used in biomass energy production and considered alternative energy sources. Also, sediments extracted from water can be recycled into materials suitable for energy production. This approach is beneficial both ecologically and economically. It not only protects the environment but also converts the mass into energy, enhancing economic efficiency. Such an integrated approach can contribute to forming a sustainable development model in the Khachmaz economic region.

Keywords: Khachmaz, water basin, renewable energy, ecology

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1.Introduction

The Khachmaz economic region, located in the north of Azerbaijan, is notable for its water bodies. Several rivers—including Gusarchay, Gudyalchay, and Gilgilchay—flow through it, along with various lakes and reservoirs. These water sources are important for agriculture, drinking water supply, and tourism. However, in recent years, human activity and climate change have disrupted their ecological balance, leading to significant pollution. Major contributing factors include household and industrial waste discharged along riverbeds and agricultural runoff containing pesticides and fertilizers, which contaminate both surface and groundwater. This degrades ecosystems, endangers aquatic species, and reduces biodiversity. Illegal sand and gravel extraction and poor management of water bodies further worsen the situation. These practices alter river flow, increase sedimentation and turbidity, and accelerate riverbank erosion, harming soil fertility. Climate change, including rising temperatures and erratic precipitation, has reduced river water levels, causing water shortages for both ecosystems and local communities. Especially during summer, reduced water availability disrupts drinking water supply and agriculture.Improving water quality requires implementing modern purification systems, regulating waste discharge, promoting sustainable agricultural practices, and fostering cooperation among local authorities and communities. If ignored, pollution and water shortages could seriously harm the environment and public health.

2. Experimental detail

Hydroecological rehabilitation is essential for ecological stability and efficient water resource use. Water bodies become polluted by domestic and industrial waste, agricultural chemicals, and petroleum products.

Mechanical purification is one primary method. It removes large solid waste and sediment using filters, nets, and barriers, including the extraction of sludge and silt using special equipment.

Chemical purification involves adding reagents that neutralize harmful substances, particularly effective against heavy metals. However, environmental side effects of these chemicals must be carefully assessed.

Biological purification is the safest and most effective method, using natural microorganisms and plants to break down pollutants. Wetland plants and bioactive materials act as natural filters, particularly useful near agricultural zones.

Modern technologies like ultraviolet light, ozonation, and nanofiltration ensure deep purification by eliminating harmful microorganisms and contaminants, especially in urban areas.

A comprehensive approach is needed: alongside purification, pollution sources must be reduced, waste management improved, and public awareness raised. Only then can a healthy aquatic ecosystem be achieved.

The mass obtained from purification has various physical, chemical, and biological characteristics. It may contain domestic, industrial, and agricultural waste residues.

Physically, it consists of sludge, silt, and solids such as plastics and wood fragments, varying by geography and pollution level.

Chemically, it includes heavy metals (lead, mercury, cadmium), pesticides, oil residues, and phosphates—especially in industrial zones—requiring special treatment before reuse.

Biologically, it includes microorganisms, bacteria, algae, and decayed plants. Some of this biomass can be used as fertilizer, though its content and toxicity must first be tested.

Energy potential is also present. Organic waste can be converted into biofuel and biogas. Algae and plant residues from water bodies are rich in energy and can be processed as biomass, reducing waste and supporting renewable energy development.

Biomass energy from organic material is one of the most widely used renewable sources. Algae and aquatic plants can be burned for heat or processed into solid fuels (pellets, briquettes).

Biogas production is another key method. Anaerobic fermentation of decayed organic material produces methane and carbon dioxide, usable for heating and electricity generation.

Biodiesel can be produced from algae rich in oils. This fuel, an alternative to diesel, supports green energy and reduces oil dependency.

Thermochemical conversion technologies such as pyrolysis and gasification further enable energy recovery. Pyrolysis breaks down biomass into bio-oil, biochar, and syngas in an oxygen-free environment, while gasification turns it into hydrogen-rich syngas suitable for various energy systems.

Using biomass from water bodies for energy helps reduce waste and promotes sustainability. It supports better resource use, reduces environmental pollution, and advances renewable energy.

ECONOMIC AND ECOLOGICAL SIGNIFICANCE

Using biomass in renewable energy systems is economically and ecologically beneficial. It reduces waste management costs, supports alternative energy development, and enhances environmental protection. Economically, this approach lowers energy production costs and creates new jobs. Biomass energy—particularly from biogas and solid fuels—helps diversify energy supplies and reduce expenses in agriculture and industry. It also alleviates pressure on existing energy networks and improves overall efficiency. Collecting, processing, and utilizing biomass opens up employment opportunities, supporting rural development and economic resilience. Ecologically, it reduces reliance on fossil fuels and lowers carbon emissions. This contributes to climate change mitigation and ecosystem preservation. Biogas and biomass reuse help lower ecological burdens. Water body ecosystems benefit directly, as purification raises water quality, supporting aquatic life and biodiversity.

3. Conclusion

The project of hydroecological rehabilitation and the use of obtained biomass in renewable energy systems has significant economic and ecological benefits. It ensures efficient use of natural resources, reduces waste, and supports the growth of alternative energy. Using biomass for energy reduces dependency on fossil fuels and fosters cleaner energy. Economically, it cuts costs in agriculture and industry, creates jobs, and strengthens energy security. Environmentally, it helps reduce carbon emissions and supports water and ecosystem restoration. This combined approach supports sustainable development and positively impacts both the environment and the local economy. With further research and technological advancements, biomass-based energy systems can be expanded regionally and globally.

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Research on the Use of Renewable Energy Sources in the Eastern Zangezur Economic Region

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Abstract: In this article, we will examine various types of energy, namely renewable and non-renewable energy sources, their differences, the advantages of renewable energy sources, and the correct methods of utilizing these energy sources, as well as their ecological and economic benefits. Additionally, we will discuss the ecology of the Eastern Zangezur Economic Region and the installation of renewable energy sources in these areas.

Keywords: Types of energy, Renewable energy sources, Economic and ecological advantages, Energy potential of the Eastern Zangezur Economic Region, Environment, and climate.

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1.Introduction

Since the beginning of life on Earth, humans have started using thermal energy to heat themselves and meet other needs. This thermal energy has been obtained by applying various methods. Energy is always present and inexhaustible; it can only change from one state to another. Examples of energy sources include the Sun, wind, water, biomass, and natural resources such as oil, gas, coal, and others. The existence of energy is also important from an economic and social perspective. If we classify the types of energy, we can identify the following:

1. Thermal energy
2. Mechanical energy
3. Kinetic energy or motion energy
4. Potential or position energy
5. Magnetic energy
6. Chemical energy
7. Radiant energy

In general, energy sources are divided into two categories: renewable and non-renewable energy. Renewable energy means that this energy is constantly available in nature and is not created by human activity. Renewable energy sources also include biomass and peat. Non-renewable energy sources are those that exist in nature but can be depleted over time. Organic and inorganic fuels are non-renewable energy sources. Organic energy sources include oil, gas, and coal. Inorganic energy sources refer to nuclear fuels. In European countries, approximately 50% of the energy is obtained from nuclear power plants. The constant increase in human demand for energy may lead to the depletion of non-renewable energy sources. The increasing cost of organic and inorganic energy sources is also a factor contributing to the reduction of dependency on them. For this reason, people are increasingly interested in using renewable energy sources like solar, water, wind, and others, and modern devices have been developed to utilize these energy sources. Despite the advantages of renewable energy sources, they also have their own challenges and can create some problems. For example, if we look at hydro resources, we can see that the installation of hydroelectric power stations poses a threat to the lives of many fish and can cause the land to be flooded in the event of an accident. These stations are usually located in cities and towns where people live. Therefore, when using such methods, careful attention must be paid, and the area must be thoroughly studied. Using renewable energy sources leads to the conservation of non-renewable energy sources like oil, gas, coal, and others, as well as keeping the environment clean. The famous Russian chemist D.I. Mendeleev expressed his views on obtaining thermal energy from oil by saying: “Using oil to obtain thermal energy is like burning paper money in a stove.” Indeed, when we think about it deeply, this is quite true. Another method of energy production is the use of nuclear energy. This method occurs through the transformation of small atomic nuclei, and the energy obtained is called thermo-nuclear energy. This process, in which small nuclei fuse and large nuclei split to form a medium-sized element, generates a large amount of energy, and it is still widely used in some countries. However, when burning fuels to obtain energy, several problems arise, because both complete and incomplete combustion occurs, which leads to the emission of harmful gases into the atmosphere. For example, carbon dioxide, which has a high heat capacity, leads to the retention of more heat in the atmosphere and contributes to global warming. Because of these issues, renewable energy sources are preferred more. Let's look at each of these energy sources. In general, we can say that solar energy is inexhaustible, always available, and when we use this energy, no carbon emissions are produced. The panels used to obtain energy from the Sun are long-lasting and require minimal maintenance. However, there are some challenges, such as the fact that obtaining this energy directly depends on the weather, the panels require a large investment, and batteries are needed to store the energy, which adds extra costs. Solar energy is used in many fields, such as meeting the electricity demand of industries and homes, agricultural sectors, and transportation. Solar energy can be applied in the following fields:

1. Photovoltaic systems: Convert sunlight directly into electrical energy. These systems are used in both small objects and large power stations.
2. Solar thermal energy systems (STES): These systems directly convert solar energy into thermal energy, which is widely used for heating buildings, residential areas, and water.
3. The process of water purification using solar energy.
4. The use of solar energy to power transportation.
5. Solar power stations: These stations enable the large-scale collection and use of solar energy in various fields.

The widespread use of solar energy reduces the amount of carbon dioxide released into the environment and helps prevent additional energy costs. Installing these systems requires a significant initial investment, and the geographical conditions and climate of the installation site must also be carefully considered. Wind energy is generated by converting the mechanical movement of the wind into electrical energy, and it is considered a renewable energy source. As with all renewable energy sources, wind energy is obtained without harming the environment and without generating carbon dioxide, thus contributing to the fight against climate change. Among all renewable energy sources, wind energy is one of the most efficient due to its low production cost, environmental cleanliness, and inexhaustibility. Wind is formed due to the difference in pressure on the Earth's surface and the changes in atmospheric temperature. Wind power plants are much quicker to install compared to other power plants, and the production process of wind energy plants is one of the most cost-effective. Wind energy plants are in high demand because they can be installed in more countries compared to other types of power plants. Hydropower is the energy obtained from the movement of fast-flowing water. This energy involves converting the kinetic energy of fast-flowing water into electrical energy with the help of special turbines. The process of obtaining energy from hydropower is as follows: first, the potential energy of fast-moving water starts moving turbines, and these turbines, in turn, power a generator, which produces electricity. Hydropower, like other renewable energy sources, is considered renewable because the water cycle in nature is continuous, and the energy is obtained cleanly without harming the environment. The process occurs in five stages: water is stored in a reservoir, creating a height difference that leads to the accumulation of potential energy. The water is then directed through pipes to turbines, where it causes them to move, and the turbines, in turn, power a generator to produce electricity. Finally, transformers and power lines distribute and transmit the electricity. In Azerbaijan, there are more than 10 hydroelectric power stations (HEPS), with the largest being the Mingachevir Reservoir, which is not only the largest in Azerbaijan but also in the South Caucasus. The Mingachevir hydroelectric power station, with a height of 80 meters, width of 1550 meters, and six turbines, has a capacity of 420 MW. It began operations in 1954 and was re-commissioned on February 27, 2018, following renovation work, with President Ilham Aliyev attending the ceremony. Biomass energy is a form of chemical energy that can be obtained from living organisms and their remains. This energy is a converted form of the solar energy stored in plants through photosynthesis. Plants absorb carbon dioxide (CO_2) and store carbon, which is then converted into a carbon-based energy source. Over time, these materials become energy sources. Biomass energy can be categorized into:

1. Plant-based biomass: Wood, straw, sawdust, corn stalks.
2. Animal-based biomass: Animal manure, food industry waste.
3. Solid, liquid, and gas forms of biomass: Solid biomass includes agricultural waste and firewood. Liquid biomass includes biodiesel and bioethanol. Gas biomass includes biogas (a mixture of CH_4 and CO_2) and syngas (a mixture of CO and H_2).

The Eastern Zangezur Economic Region: The Eastern Zangezur Economic Region was established by a decree of the President of the Republic of Azerbaijan on July 7, 2021. According to this decree, the economic regions of Azerbaijan were divided, and the Eastern Zangezur Economic Region was recognized as an independent entity. The Eastern Zangezur Economic Region includes the following districts:

1. Kalbajar
2. Lachin

3. Gubadli
4. Zangilan
5. Jabrayil

The naming of this region holds both historical and symbolic significance. The Eastern Zangezur Economic Region is rich in natural resources, has a favorable geographic location, and possesses significant renewable energy potential. As President Ilham Aliyev stated: "We will revive Eastern Zangezur, and this region will become one of the centers of Azerbaijan's economy and ecological development." Efforts are being made to establish a green energy zone in these areas, as well as to build smart villages and cities. The regions of Lachin, Kalbajar, and Zangilan in Eastern Zangezur have rich solar, wind, and hydropower potentials. The Karabakh and Eastern Zangezur regions are among the leading areas in Azerbaijan in terms of solar energy potential. The annual solar radiation in these regions is about 1600-1700 kWh/m^2, and the annual sunshine hours range from 2500 to 3000 hours. The districts with the highest solar potential are Gubadli, Zangilan, and Jabrayil, making it possible to install solar power plants. The high mountains in Kalbajar, Gubadli, and Lachin also have a very high wind energy potential. The average wind speed in these areas is 6-8 m/s, which is suitable for installing wind turbines. Currently, the construction of wind power stations in this area is being planned. The rich rivers of the Karabakh and Eastern Zangezur regions also provide opportunities for hydropower generation. It is quite feasible to build small and medium-sized hydropower plants in this area. Examples of major rivers include Tartarchay, Hakerichay, Khachinchay, and Bazarchay. The high annual water flow rate also indicates a high energy potential. The Gulabird Hydropower Station, with a capacity of 8 MW, operates on the Hakerichay River in the Lachin district. Although it was illegally constructed in 2004, it began its legal operation after the liberation of the Lachin district in 2020. The annual energy production of the Gulabird Hydropower Station is 22 million kWh, which is enough to meet the energy needs of more than 5,000 families. As a result, this region has enormous renewable energy potential, and the development of these sources will have a significant impact on ensuring energy security in the country and reducing carbon emissions. The renewable energy resources in Eastern Zangezur provide an opportunity to create a sustainable energy supply. These sources will be further developed in the coming years, leading to increased energy independence and a cleaner environment.

Conclusion

The use of renewable energy sources in Azerbaijan, especially in the Eastern Zangezur Economic Region, plays a key role in both environmental protection and economic development. The vast energy potential of solar, wind, and hydro resources in this region presents significant opportunities for renewable energy projects that will meet local energy demands and contribute to Azerbaijan’s energy security.

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Investigation of Artificial Intelligence Tools in Smart Cities

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Abstract: The advent of swiftly progressing technology has created a pathway for smart cities, where Artificial Intelligence (AI) is key to improving life in urban areas. This research delves into how AI is being used and what it's doing in smart city projects. The focus is on things like traffic flow, how efficiently energy is used, keeping the public safe, tracking the environment, and providing services to citizens. The study examines recent real-world examples and case studies. It emphasizes how AI tools—think machine learning, computer vision, and predictive analysis—are helping to make urban infrastructure better and make it easier to make good choices. This paper will also discuss the difficulties of bringing AI to cities. Topics include protecting data, ethical dilemmas, and the necessity of strong rules. By looking at what's happening now and what's expected to happen, this study offers important understanding on how AI can help cities grow in a sustainable and intelligent way.

The evolution of smart cities marks a profound change in the way we build and manage our urban spaces. It harnesses cutting-edge technology to foster more effective, eco-friendly, and comfortable living environments. Within this technological landscape, Artificial Intelligence (AI) emerges as a pivotal component, providing novel instruments and architectures that facilitate instantaneous data analysis, automated processes, and intelligent choices. This document provides a detailed examination of the part and the capabilities of AI solutions in smart cities, exploring how these technologies are modifying the structure of urban centers across a range of areas.

This research prioritizes key sectors where AI has demonstrated noteworthy influence, like intelligent transportation management, where machine learning algorithms are employed to optimize traffic movement and alleviate traffic jams; energy management frameworks that use predictive analytics to reconcile supply and demand; environmental surveillance, incorporating computer vision and the Internet of Things for immediate monitoring of pollution and trash; public safety, where AI-driven surveillance and predictive policing are aiding in preventing crime; and resident interaction platforms, that use natural language processing to refine public services and reactivity. Using an analysis of current global case studies—like Singapore's AI-led city planning and Barcelona's innovative waste administration—this document showcases the real advantages and quantifiable results from utilizing AI. Furthermore, it examines the core data frameworks necessary for these tools to work correctly, underlining the importance of big data, cloud computing, and 5G connectivity. Nonetheless, the document also deals with significant obstacles and drawbacks, including anxieties about data privacy, biases in algorithms, cybersecurity threats, and the need for comprehensive digital administration. Ethical issues, together with the value of transparency and accountability in AI systems, are reviewed, along with policy suggestions for regulatory bodies and city designers. By merging current research and practical uses, this paper endeavors to deliver a full understanding of how AI tools are driving the progression of smart cities and what future opportunities and risks are foreseen. It contributes to ongoing dialogue concerning long-term urban innovation and gives vital perspectives for legislators, technologists, and urban developers.

Keywords: Artificial Intelligence, AI, computing, smart city

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1.Introduction

The definition of smart cities has evolved significantly over time, and the concept has come to encompass a variety of interpretations and aspects [1]. Early discussions laid the foundation for this concept by acknowledging the complexity of smart cities. Harrison et al. [2] provided a broad analysis that highlighted how different technologies, data sources, and systems can be integrated to improve urban performance. Caragliu et al. [1] noted the important role of information and communication technologies (ICTs) in increasing the efficiency and competitiveness of cities. As the concept has evolved, more attention has been paid to the importance of sustainability in smart city projects [3, 4]. This shift has led to the emergence of a broad approach that relies on innovative technologies and data-driven strategies to address environmental, social, and economic challenges [2]. Researchers and experts have used various methods and indicators to define smart cities. Sustainability is a key element of these efforts and includes efforts to reduce resource consumption, promote the use of renewable energy, and improve the environment [5, 6]. The concept of "smartness" is often associated with the implementation and use of advanced technologies, and these technologies play a key role in the definition of smart cities [7, 8]. Performance indicators are used to measure how successful and efficient projects are. These indicators cover various areas such as governance, innovation, quality of life and economic development. Through these indicators, researchers and policymakers aim to assess and compare the level of "smartness" of different cities. This approach reveals the increasing integration of IoT technologies and artificial intelligence towards making urban environments more sustainable and efficient. Standard methods commonly used to identify smart cities rely largely on manual data collection and subjective assessments. This dependency creates limitations in terms of scalability, objectivity, and accuracy. Machine learning (ML) offers a potential solution to these limitations by offering innovative analysis methods and tools. Machine learning is widely applied in various fields due to its predictive capabilities and ability to detect significant patterns in large data sets. In the smart city field, ML offers promising opportunities in terms of improving identification and assessment processes. The aim of this study is to examine and evaluate a wide range of artificial intelligence (AI) tools used in smart cities. The focus is on understanding what these tools do, how they are implemented, and their overall impact on urban development. The study seeks to clearly identify how AI contributes to improving city operations, improving public services, and creating sustainable, highly efficient urban environments. In addition, the study aims to assess the challenges and ethical issues faced when implementing AI in smart city systems, providing an overview of future trends and potentially effective strategies for successful implementation. The main objective of this study is to fully analyze how various AI tools work and how effective they are in smart cities. Due to the increasing urban challenges such as demographic growth, resource management and environmental sustainability, smart cities are using technologies such as AI to improve the quality of life. This study was designed to explore various AI solutions applied in important urban areas such as transportation, energy management, environmental monitoring, public safety and citizen participation. Through detailed analysis, the study seeks to explain how AI-based solutions such as machine learning algorithms, computer vision, natural language processing, and predictive analytics are being used to improve urban infrastructure, increase operational efficiency, and enable data-driven decision-making. It also identifies the benefits these technologies bring in terms of reducing congestion, increasing energy efficiency, enhancing safety measures, and increasing the agility of public services. The study also examines the challenges and limitations of applying AI to urban environments. These include data privacy, ethical issues, transparency of AI algorithms, and the importance of rules governing the responsible use of AI. By examining these aspects, the study aims to provide a broad understanding of the current state and future potential of AI tools in the development of smart cities.

Finally, the main goal of this study is to provide valuable recommendations and suggestions for policymakers, urban planners, and technology developers. The goal is to guide the sustainable and ethical integration of AI in smart cities, thereby supporting the formation of smarter, more productive, and more livable urban environments in the future.

2.Experimental detail

The methodology used in this study attempts to cover the topic from both theoretical and practical aspects. The following methodological approaches were used to achieve the objectives of the study:

Our study takes a multidisciplinary approach to deeply investigate how artificial intelligence (AI) is used in the context of smart cities. Our main methods are as follows:

Literature Review:

Our research is based on a comprehensive review of existing academic work. To understand the role of AI in the development of smart cities, academic publications, industry reports and practical case studies were carefully analyzed. Search queries were conducted in databases such as IEEE Xplore, ScienceDirect and Google Scholar with keywords such as "AI and smart cities", "machine learning for urban applications" and "smart city technologies".

Case Study Analysis:

Reputable smart city projects that have already implemented AI technologies in various cities around the world - cities such as Singapore, Barcelona and Amsterdam - were selected as examples. The application of AI in these cities in the areas of traffic regulation, energy distribution optimization, public safety and environmental monitoring was examined in detail.

Qualitative Analysis:

Semi-structured interviews were conducted with representatives of urban planning, IS design and development, and city management. The aim of the interviews was to gather expert opinions on the advantages and challenges of implementing IS in smart cities. These discussions helped to contextualize the literature and case study findings.

Data Evaluation:

The qualitative data collected was thematically analyzed and relevant examples were extracted. At the same time, quantitative data obtained from the case studies were analyzed to assess the impact of IS on performance indicators such as traffic congestion reduction, resource efficiency, and changes in crime rates.

Framework Development:

Based on the collected data, a comparative framework was created to assess the effectiveness and level of development of AI tools in various smart city programs. This assessment took into account important factors such as technological feasibility, scalability, and ethical issues.

The integration of a multi-method approach has generated a rich and broad understanding of how AI is changing the nature of smart cities. This comprehensive study aims to identify the practical benefits of AI and the operational challenges that arise during its implementation.

The combination of disruptive technologies, including artificial intelligence (AI), the Internet of Things (IoT), and cloud computing, is transforming healthcare into smart systems. Figure 1 illustrates the application of smart healthcare in a smart city environment. These technologies play a critical role in personalizing, simplifying, and optimizing healthcare services.

In addition, these innovations enable real-time health monitoring through wearable devices or mobile health apps downloaded onto smartphones, encouraging people to actively manage and control their personal health.

Moreover, health data generated by patients is securely transmitted to doctors and medical professionals via cloud platforms, where it is then used for diagnostics and consultations.

Furthermore, in the field of health screening, Artificial Intelligence (AI) can be applied to facilitate early detection of diseases and strategic selection of appropriate treatment methods. Source [1] has examined the ethical issues associated with relying on "black box" operations in AI systems, as well as the transparency of AI frameworks and their applications.

The methodologies used to explain the working mechanism of AI, including the reasons for its predictions, are generally known as Explainable Artificial Intelligence (AI) techniques. Source [4] also recommends the incorporation of AI techniques into existing AI methods in order to increase the predictive accuracy of AI-based models used in healthcare.

The following points summarize some of the advantages of applying AI in healthcare:

• Interpretation of Results: By leveraging the explanatory capabilities of AI techniques, it is possible to track and understand the factors that influence the outcomes of AI-based systems.

• Increased Transparency: AI enhances trust and increases transparency by explaining the decision-making processes in AI systems.

• Model Improvement: The explanations provided by AI are useful in the model improvement process, helping to identify errors and increase the accuracy of the AI system that learns from data. In AI systems, incorrect predictions based on faulty logic often occur; AI supports the elimination of these shortcomings.

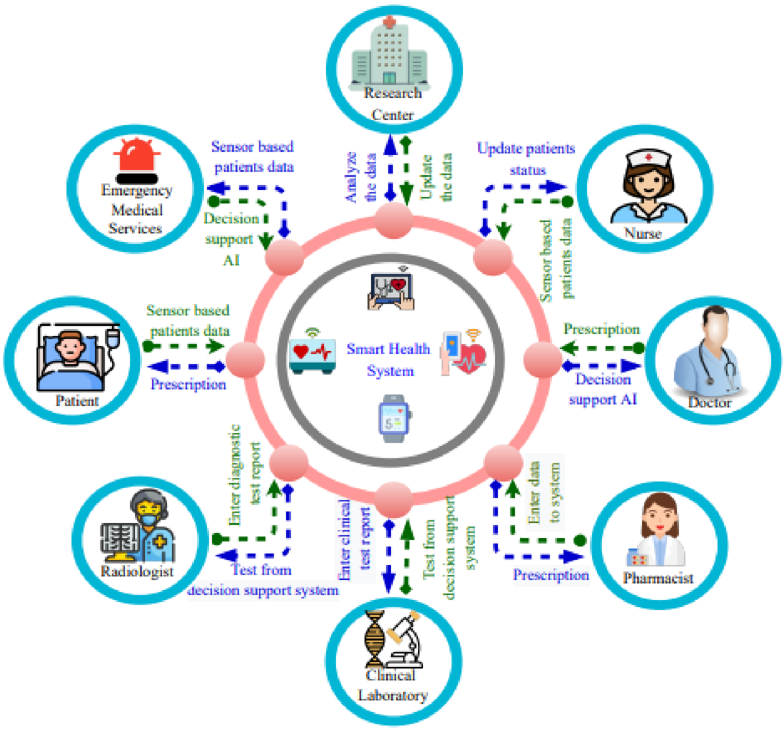

Figure 1. Smart healthcare system in smart cities.

3. Conclusion

This study presents a new assessment system that combines multidimensional data analysis with various machine learning models to assess the level of "smartness" of cities on a global scale. This methodology provides a comprehensive approach to understanding and evaluating the performance of smart cities, covering both structural and technological indicators. Machine learning algorithms such as Artificial Neural Network (ANN), Random Forest (RF), Support Vector Machine (SVM), and XGBoost (XGB) have demonstrated high predictive ability based on specific indicators to determine the level of smartness of cities. The different contributions of each model highlight the multifaceted structure of urban smartness. The main findings highlight the significant impact of technological integration on the classification of a city as "smart". Furthermore, increasing citizen participation and enhancing urban mobility through smart applications play a crucial role in building agile, efficient and sustainable urban environments. The consistent key indicators found across different models demonstrate how this approach is a powerful framework for cities seeking to improve their smart city status. In conclusion, this study provides a comprehensive and in-depth analysis of the key elements that characterize smart cities. Using machine learning techniques and improved methodological frameworks, our understanding of the concept of urban "smartness" has been broadened and a more data-driven, in-depth view has been developed. This supports practical decision-making and strategic urban planning. The idea put forward at the beginning – that machine learning models used in conjunction with large urban datasets can successfully and accurately identify the key characteristics of smart cities – is confirmed by this study. The study enriches the growing body of knowledge on smart city assessment and provides practical and actionable information for urban planners and policymakers to build more livable, inclusive and sustainable urban environments.

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Modern and independent stages in the integration of science and education in Azerbaijan

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Abstract: The integration of the education policy of modern and independent Azerbaijan is undoubtedly connected with the name of our National Leader Heydar Aliyev. Thus, in our modern Azerbaijan, the sending of bright young people of the future to leading higher education institutions of foreign countries, the opening of new universities, and the provision of state support for the training of qualified personnel were continued by the Great Leader in the same way in independent Azerbaijan. In the article I wrote, the development of the stages of education in modern and independent Azerbaijan was studied and investigated during the periods led by the National Leader.

Key words. Heydar Aliyev, science, education, integration, development, modern, independent

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1.Introduction

At the age of 28, Heydar Aliyev, whose endless love and passion for education never ended, was admitted to the History Faculty of Azerbaijan State University (now Baku State University) and completed his education with excellent grades and an honorary diploma. [4] In the following years, his departure to Leningrad to study in his profession was one of the endless gifts that life presented to him. In 1969, our National Leader, who was appointed First Secretary of the Central Committee of the Communist Party of Azerbaijan, thought about the future with great wisdom, pulled the education policy out of the swamp and established a new development model [1].

2.Experimental detail

Modern Azerbaijani education in the phenomenality of H. Aliyev. In the 1970s and 1980s, the national leader created the opportunity and conditions for Azerbaijani youth to study and be trained as skilled specialists in more than 250 specialties, covering more than 80 areas of national economy, science, education and culture of our republic, in the most famous higher schools of the former USSR, outside Azerbaijan. [3] By the way, if in 1970 the number of students sent to study outside the republic was 60, in 1975 their number reached 3590, in 1978 it reached 7850, and in 1980 their number was 11000. This also created the opportunity to further strengthen the national personnel potential of the republic.

As a result of the decisions adopted in 1972 "On completing the transition of young people to general secondary education and further developing general education schools" and in 1973 "On further improving the working conditions of rural general education schools", the network of secondary general education schools in Azerbaijan was expanded 3 times, from 765 to 2,117. This meant the opening of secondary general education schools in hundreds of remote settlements and the involvement of thousands of minors in education. During the years when Heydar Aliyev led Soviet Azerbaijan, 5 new higher education institutions were opened in the country and the number of students studying in higher education schools increased from 70,000 to 100,000 [2].

At the initiative of Heydar Aliyev, a military lyceum was established in 1971 on the basis of 8-year boarding school No. 2 in Baku, which increased the interest of young people in the military. In 1997, by the order of Heydar Aliyev, the name of the lyceum was changed to Jamshid Nakhchivansky Military Lyceum. The award for this service of the national leader was made by the Order of the President of the Republic of Azerbaijan Ilham Aliyev dated February 27, 2004. According to the order, the Nakhchivan branch of the Jamshid Nakhchivansky Military Lyceum was abolished and the Heydar Aliyev Military Lyceum was established on its basis. About 1,000 graduates of the lyceum were awarded various orders and medals, 11 of whom were awarded the honorary title of National Hero of Azerbaijan, and 19 were awarded the title of Hero of the Patriotic War [4,6].

The years of optimal development of independent Azerbaijani education (1993-2003). In independent Azerbaijan, there were two main issues that Heydar Aliyev always attached great importance to in education. The first was the mother tongue, and the second was the history of Azerbaijan. This great personality always prioritized the supremacy of the mother tongue and emphasized that this work was directly related to education for its protection. According to Heydar Aliyev, the mother tongue was the fundamental principle of Azerbaijaniness. Therefore, in order to instill national and spiritual values in the people, he knew well the importance of protecting and developing their own language first of all. At the same time, it is worth remembering that the Great Leader made all his official speeches in Azerbaijani at that time and recommended this to all senior officials. He demanded that the history of Azerbaijan be taught and taught as it is [5].

The Orders “On strengthening the relevant technical base of secondary schools in the Republic of Azerbaijan” dated October 4, 2002, and “On approval of the program for the construction, overhaul and provision of new secondary schools with modern educational equipment in the Republic of Azerbaijan (2003–2007)” dated February 17, 2003 laid the foundation for the expansion of the network of secondary schools, as well as the strengthening of their material and technical base. While 1 million 549 thousand students received education in 4364 secondary schools of the republic in the 1993–1994 academic year, more than 1 million 600 thousand teenagers continued their education in 4561 secondary schools in the 2002–2003 academic year. Also, 200 new school buildings were built and put into operation, and more than 700 secondary schools were organized in the regions and cities where internally displaced persons temporarily settled [4]. In order to develop the abilities of talented children, about 30 lyceums and gymnasiums were organized, attracting about 12 thousand students.

The XI Congress of the "Independent Azerbaijani Teachers" on September 25, 1998 can be considered the brightest period in the field of education. For the first time, the anthem of Azerbaijani teachers was sung at that congress. Heydar Aliyev participated in the congress until the end of the event. This step was once again a clear example of Heydar Aliyev's respect for the teaching profession. At the same time, it is clear from the research that from 1998 to the present day, more than 1,500 employees of scientific research institutions and universities have been on creative missions to various countries - the USA, Great Britain, Russia, Turkey, Germany, Greece and other countries, representing Azerbaijani science at a high level. The author of this great success was Heydar Aliyev [3].

3. Conclusion

Heydar Aliyev said: “Education is the future of the nation”. The path of development of science and education policy, which our national leader Heydar Aliyev assessed as one of the fateful issues, has been continued by his worthy successor, Mr. Ilham Aliyev, with the same wisdom and foresight since 2003. The successes achieved in the last 20 years, the achievement of high international results by our higher education institutions, the formation of material and technical bases in higher and secondary education institutions, the victories of our modern youth in international science and Olympiads, the signed Decrees and State Programs, etc. are a clear example of a sustainable development model in education.

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Anthropogenic impacts on nature

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Abstract: In the contemporary world, human activities have increasingly caused profound anthropogenic impacts on the natural environment, posing serious threats to the stability and health of ecosystems. Rapid industrialization has led to widespread pollution through the release of harmful chemicals and waste products, which contaminate air, water, and soil resources. Urbanization accelerates habitat destruction and fragmentation, reducing green spaces and biodiversity in many regions. Moreover, the intensive use of chemical fertilizers, pesticides, and herbicides in modern agriculture further exacerbates environmental degradation by polluting water bodies, disrupting soil fertility, and harming non-target species. Together, these factors contribute to the acceleration of climate change, which manifests through rising global temperatures, altered weather patterns, and increased frequency of extreme natural events. These environmental changes not only threaten the survival of countless plant and animal species but also undermine human well-being by increasing health risks associated with pollution, heatwaves, and emerging diseases. The global COVID-19 pandemic has vividly demonstrated the critical importance of maintaining a balanced and respectful relationship between humanity and nature. It served as a stark reminder that disruptions in natural ecosystems can have far-reaching consequences for human societies, including the emergence and spread of zoonotic diseases. This crisis reinforced the urgency of adopting holistic approaches that integrate environmental conservation with public health and economic development goals. The thesis emphasizes the necessity of coordinated actions at both global and local levels to safeguard ecological stability. It highlights the importance of implementing sustainable practices such as reducing carbon emissions, protecting natural habitats, promoting renewable energy sources, and fostering environmental awareness among communities. By doing so, societies can work towards achieving long-term ecological balance, preserving biodiversity, and ensuring a healthy and resilient environment for future generations.

Keywords: Anthropogenic impact, ecological balance, climate change, biodiversity, industrialization

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1.Introduction

In modern times, environmental protection and efficient use of natural resources are one of the most pressing problems facing humanity. As a result of industrialization, urbanization, intensification of agriculture and expansion of transport systems, the impact of human activity on nature has increased sharply. Such impacts are called anthropogenic impacts in the scientific literature and take various forms, from climate change to the reduction of biodiversity, soil degradation and pollution of water resources. The impact of anthropogenic factors on nature has serious consequences not only in ecological, but also in socio-economic and cultural aspects. Disruption of the natural balance poses a direct threat to human health, food security and the sustainability of ecosystems in the long term. Therefore, the formation of ecological thinking, the application of the principles of sustainable development and the strengthening of environmental protection measures are of strategic importance today. In modern times, the rapid development of technology and industrialization, dynamic population growth and the expansion of urbanization have sharply increased the anthropogenic impacts of human activity on nature. These processes, especially in recent centuries, have led to the expansion of the scale of human influence on nature, disrupting the natural balance of ecological systems. Intensive and sometimes uncontrolled interference of human activity with nature leads to the pollution of basic natural resources such as water, air and soil, the reduction of biological diversity and the functional disruption of ecosystems. As a result, these ecological imbalances pose serious threats to human life itself and endanger the living conditions of future generations. In the 21st century, climate change has come to the fore as the most urgent and complex problem on a global scale. As a result of the increase in the amount of greenhouse gases released into the atmosphere, especially carbon dioxide (CO_2), methane (CH_4) and nitrogen oxides, the average surface temperature of the Earth is constantly rising. This warming process is causing the rapid melting of glaciers, the reduction of polar ice caps and the rise in the level of the world's oceans. The rise in ocean levels, in turn, puts numerous human settlements located on low-lying coasts at risk of flooding. At the same time, climate change is causing great damage to global ecosystems and human societies by increasing the frequency and severity of droughts, floods, hurricanes and other natural disasters. These processes are also leading to the destruction of ecosystems, including tropical forests, coral reef systems and various species of living things [1-7].

2.Experimental detail

One of the main causes of climate change is the excessive and unplanned intervention of human activities in nature, in particular the extensive use of fossil fuels, industrial emissions and massive deforestation.

Figure 1. Anthropogenic impacts on nature

In addition, although the chemicals widely used in modern agricultural technologies – pesticides, herbicides and synthetic fertilizers – temporarily increase soil fertility, they disrupt the structure and chemical composition of the soil organism in the long term. These chemicals damage the natural microorganisms of the soil, weakening its biological activity and, as a result, causing soil erosion and a decrease in productivity. At the same time, pollution of groundwater and surface water sources, especially the toxicity of groundwater with pesticide and fertilizer residues, poses a serious threat to the environment and human health. When these polluted waters are used in agriculture, drinking water and other economic sectors, they have a negative impact on the human and animal body in a chain reaction [2].

As a result of the rapid growth of cities and the expansion of infrastructure, there is a decrease in green areas, parks and natural landscapes. This trend worsens the quality of the environment in which the urban population lives. Air pollution, especially the deterioration of air quality as a result of the release of automobile and industrial waste into the atmosphere, poses a great threat to public health. Increasing noise levels and difficulties in waste management negatively affect the quality of life of city dwellers, increasing stress levels and creating conditions for the development of various diseases. In addition, the transformation of natural landscapes and the destruction of forest cover lead to a decrease in biodiversity, the extinction of rare and endangered species. These processes weaken the resilience of natural ecosystems, lead to a disruption of the ecological balance and generally reduce the ability of nature to restore itself [3].

Table 1. Key Environmental Challenges and Their Impacts

Topic	Description	Outcome / Impact
Technology and Industrial Growth	Rapid increase in human activities and urbanization intensifies anthropogenic impacts on nature.	Disruption of ecological balance and deepening of environmental issues.
Climate Change	Global warming occurs due to the increase of greenhouse gases in the atmosphere.	Melting glaciers, rising sea levels, and increased natural disasters.
Chemical Use in Agriculture	Pesticides, herbicides, and fertilizers may boost short-term productivity but cause long-term environmental harm.	Disruption of soil chemistry, contamination of groundwater, and harm to living organisms.
Urban Expansion and Infrastructure	Reduction of green areas, air and noise pollution, and waste management problems due to urban growth.	Decrease in quality of life and loss of biodiversity.
Loss of Biodiversity	Transformation of natural landscapes and deforestation lead to species extinction.	Weakening of ecosystems and disruption of ecological balance.
Solving	Climate policy, clean energy, sustainable	Key conditions for planetary

Environmental Problems	agriculture, urban planning, and biodiversity protection are essential.	sustainability and the healthy development of human society.

Thus, in modern times, such extensive and deep anthropogenic impacts on nature lead to the disruption of ecological systems and the threat to the ecological health of our planet. This poses serious challenges for the sustainable development of human society.

The pandemic period, especially the spread of COVID-19, has painfully shown us how the risk of the emergence and spread of new infectious diseases increases when a harmonious relationship with nature is not established and interference with wildlife increases. Human activities in natural ecosystems, such as illegal hunting, habitat expansion, deforestation, and wildlife trade, lead to a disruption of the natural balance and an increase in the likelihood of viruses and other pathogens passing to humans. This event has once again proven that ecological stability is possible only through the protection and restoration of ecosystems. If we do not respect nature and do not sustainably manage it, human health and safety of life will be at even greater risk in the future [4].

Against the background of all these environmental problems, countries around the world are taking various measures to prevent these threats and are strengthening cooperation at the global level in this direction. Within the framework of the Sustainable Development Goals adopted by the UN, environmental protection, combating climate change and efficient use of natural resources have been identified as priority areas. These goals aim not only to protect the environment, but also to ensure the sustainability of social and economic development. Thus, for the harmonious development of nature and human society, the transition to renewable energy sources - solar, wind, hydropower and clean energy types such as biomass - is encouraged. The use of these energy sources mitigates the effects of climate change by reducing carbon dioxide emissions and helps restore ecological balance.

On the other hand, improving waste management systems also plays an important role in modern times. Proper management, recycling and disposal of waste prevent environmental pollution and prevent the waste of natural resources. In this area, states are taking serious steps towards reducing waste, expanding reuse opportunities and implementing recycling technologies. The application of modern technologies in waste management minimizes negative impacts on human health and contributes to environmental protection [5].

In addition, it is important to expand environmental education programs. Increasing people's environmental knowledge, forming a sense of respect and responsibility for nature are key factors in the sustainable development of society. Through these programs, people are provided with knowledge about the protection of natural resources, reducing energy and water consumption, proper waste management and preventing environmental pollution. Thus, environmental education receives wide support not only at the individual level, but also at the level of communities and countries.

Table 2. Environmental Sustainability and Human-Nature Interaction

Topic	Key Issues Addressed	Significance and Impact
Pandemic and Nature Connection	The COVID-19 pandemic revealed that excessive interference with wildlife increases the risk of emerging infectious diseases.	Lack of harmony with nature leads to ecological and health crises.
Ensuring Ecological Stability	Protection of ecosystems, restoration of natural balance, and sustainable management are crucial.	The health of nature is a fundamental condition for the continuity of human life.
UN Sustainable Development Goals	Environmental protection, combating climate change, and efficient use of natural resources are top priorities.	Provides a universal framework for global sustainable development and strengthens international cooperation.
Transition to Renewable Energy	Increasing the use of clean energy sources such as solar, wind, hydro, and biomass.	Reduces carbon footprint, slows down climate change, and enhances energy security.
Waste Management	Development of systems for recycling, reduction, safe disposal, and proper waste management.	Reduces environmental pollution, preserves natural resources, and decreases health risks.
Environmental Awareness Programs	Enhancing public ecological responsibility, promoting respect for nature, and encouraging sustainable lifestyles.	Raises community's environmental knowledge and builds public support for natural resource conservation.
Global and Local Actions	International cooperation, national legislation, strategic planning, and increased civic engagement.	Crucial for effectively addressing ecological challenges and ensuring sustainable development.
Future Perspectives and Challenges	Addressing climate change, protecting natural resources, and balancing social justice with economic development.	Balancing all aspects of sustainability to create a livable world for both humans and nature.

In general, measures taken at the global and local levels, including intergovernmental cooperation, national legislation and strategic planning, play an important role in solving environmental problems. In order to ensure the well-being of people and nature, it is important to create a balance between all aspects of sustainable development - social justice, economic growth and environmental sustainability. In the face of these challenges, systematic work should be carried out to develop sustainable and environmentally friendly technologies, manage resources without harming nature, as well as increase the ecological culture of society. Only in this way is it possible to build a healthy and habitable planet for future generations. As a result, in modern times, the anthropogenic impact of human activity on nature has led to the emergence of serious environmental problems at the global level. As a result of industrialization, urbanization and the widespread use of chemicals in agriculture, the environmental balance has been disrupted, climate change has accelerated and biodiversity has significantly decreased [6]. These processes have a negative impact not only on nature, but also on human health and the sustainability of socio-economic development. To solve such complex problems, states should implement a consistent and comprehensive environmental policy, strengthen international cooperation and accelerate the transition to clean energy sources. At the same time, every individual should be careful and responsible towards nature, increase ecological awareness, and support the protection of natural resources. Otherwise, the consequences of damage to nature will be irreversible, resulting in the destruction of ecosystems, deterioration of human health, and disruption of social stability. In order for future generations to live on a habitable, healthy, and sustainable planet, it is vital to live in harmony with nature, be guided by the principles of sustainable development, and protect natural resources. Steps taken in this direction are the greatest investment in the future of humanity.

3. Conclusion

Because of this, human-made changes to nature cause big environmental concerns today. States, society, and each person must all act responsibly in order to fix these challenges. If we don't treat nature with care and follow the rules of sustainable development, we will cause ecological damage and permanent effects. The measures that will be made today will determine whether or not the earth will be healthy and livable for future generations.

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The role of people in ecology

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Abstract: The role of people in ecology is the basis of the complex relationship between nature and society. As a result of their activities, natural resources are rapidly depleted, water and air are polluted, and ecosystems are seriously damaged. Industrialization, intensive agriculture, and urbanization processes have a negative impact on the natural environment, which leads to a decrease in biological diversity. However, the development of environmental education increases people's responsibility towards nature and causes them to focus on environmental protection. Environmental legislation, in turn, ensures the protection of the natural environment by strengthening control over polluting factors. The principles of sustainable development, in turn, allow for the preservation and restoration of ecological balance. Responsible behavior of people creates the basis for the preservation of a healthy and balanced natural environment for future generations. Thus, people act as both the cause of problems in ecology and the main actor in their solution. In addition to their impact on nature, their activities also play an important role in ensuring the sustainability of ecosystems. Therefore, the correct direction of the human factor through environmental policy and education is a key condition for environmental protection.

Keywords: Humans, environmental impact, responsibility, sustainable development, nature protection

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1.Introduction

The role of humans in ecology is perceived both as a factor influencing nature and as a protector of the environment. Human activities cause various changes in ecosystems, which can be both negative and positive. Industrial development, agriculture, and urbanization are among the key drivers of ecological problems. Pollution of the air, depletion of water resources, and soil erosion are some of the negative impact's humans have on nature. On the other hand, humans can play an active role in the restoration and conservation of natural habitats. Projects focused on reforestation, the use of clean energy, and environmental protection initiatives serve as positive examples of human engagement. Increasing ecological awareness and education improves people's attitudes toward nature. Behavior aligned with the principles of sustainable development is crucial for maintaining ecological balance. Responsible and conscious human activity is a fundamental condition for environmental protection. Therefore, the role of humans in ecology encompasses both the creation of problems and the development of solutions. Moreover, the interconnectedness of human societies and natural systems means that environmental changes directly affect human well-being and economic stability. Climate change, biodiversity loss, and resource scarcity pose significant risks that require urgent collective action. Modern environmental challenges highlight the necessity for integrating ecological knowledge into policy-making, industry practices, and everyday life. Innovations in technology and green infrastructure offer new opportunities for mitigating environmental harm while supporting economic growth. Collaborative efforts between governments, businesses, and communities are essential to foster sustainable development. As global awareness rises, there is a growing recognition that preserving the environment is not only a moral obligation but also critical for securing the future of humanity. Ultimately, empowering individuals through education and encouraging sustainable lifestyles can transform humans from passive consumers into active stewards of the Earth. The role of humans in ecology is diverse and complex. In the modern era, human activities form the fundamental basis for the dynamic interactions between nature and society. Human beings affect ecosystems both positively and negatively, shaping environmental conditions on a global scale. However, in recent decades, the negative impacts of human activity have become more prominent, contributing significantly to the rise of ecological problems. Accelerated economic growth, industrialization, intensive agriculture, rapid urbanization, and other human-induced processes have led to profound changes in the natural environment. These transformations have caused the rapid depletion of natural resources, degradation of fertile soils, and severe pollution of air and water resources. As a result, biodiversity is diminishing, numerous plant and animal species are becoming extinct, and ecological balance is being disrupted [1-6].

2.Experimental detail

Industrial enterprises release harmful gases, dust, and chemicals into the atmosphere, which contribute to climate change. These emissions create the greenhouse effect, leading to global warming. The consequences of global warming manifest in different ways around the world, including increased frequency and severity of natural disasters, melting glaciers, and rising sea levels. Such phenomena threaten the stability of ecosystems, human settlements, and economic systems.

Unsustainable agricultural practices also contribute heavily to environmental degradation. The extensive use of chemical fertilizers and pesticides causes soil erosion and depletes water resources. This not only reduces agricultural productivity but also weakens the sustainability of farming systems. The rapid growth of cities leads to the destruction of natural habitats, forcing wild animals and plants to lose their living environments and putting biodiversity under severe threat.

Yet, human activity is not limited solely to harming nature. In the contemporary world, people also play an important role in the protection and restoration of ecological systems. This positive development is closely tied to the emergence of the concept of sustainable development and the rise of environmental education. As humans develop a greater sense of responsibility toward the environment, they begin to use resources more efficiently and sustainably and to implement measures aimed at protecting nature [2].

Figure 1. The role of humans in ecology

Activities such as waste recycling, efficient use of energy and water resources, and environmental monitoring demonstrate active human participation in restoring ecological balance. These practices reflect a shift in attitude from exploitation to stewardship of natural resources. For instance, recycling programs reduce landfill waste and conserve raw materials, while energy- saving initiatives help lower carbon emissions and combat climate change. At the governmental level, environmental legislation and regulations have been established to reduce the negative effects of human activity on nature. These laws impose mandatory compliance with ecological standards on both industries and individuals, increasing control over polluting factors. State programs and greening initiatives engage citizens in environmental projects, encouraging the preservation and expansion of green spaces such as parks and urban forests. Public awareness campaigns serve to increase ecological literacy and foster a cultural shift toward sustainability, supporting the formation of environmental consciousness across society [3].

Such comprehensive approaches enable humans to actively contribute to the sustainability of ecosystems and the protection of the environment. Their involvement ensures that natural systems remain resilient and balanced, supporting the well-being of current and future generations. Therefore, the role of humans in ecology should not be seen solely as agents of environmental degradation, but also as key actors in conservation and sustainable development. Strengthening environmental education, enforcing effective governmental ecological policies, and promoting responsible behavior at the individual level are essential prerequisites for addressing today’s ecological challenges. The responsible approach and cooperation of all members of society in relation to the environment are vital for ensuring the planet’s future. Without this collective commitment, ongoing ecological degradation will continue to threaten biodiversity, ecosystem services, and human health.

Economic Development and Environmental Degradation

The rapid pace of economic development and industrialization in the last century has brought considerable wealth and improved living standards for many people worldwide. However, this progress has come at a significant environmental cost. Industrial activities emit vast quantities of pollutants, including greenhouse gases like carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). These gases contribute to the greenhouse effect by trapping heat in the atmosphere, resulting in global warming and climate change. The repercussions of these changes include altered weather patterns, more frequent and intense extreme weather events such as hurricanes, floods, droughts, and wildfires. Additionally, industrial pollution contaminates air, water, and soil, causing health problems for humans and other organisms. For example, air pollution increases respiratory illnesses, while water pollution threatens aquatic life and compromises drinking water supplies. These environmental challenges are particularly acute in developing regions where environmental regulations may be less strictly enforced [4].

Table 1. Impact of economic development on environmental degradation

Aspect	Description	Environmental Impact	Consequences
Economic Development & Industrialization	Rapid growth and industrial activities globally	Emission of greenhouse gases (CO_2, CH_4, N_2O)	Global warming, climate change
Greenhouse Gas Emissions	Emission of CO_2, CH_4, N_2O from factories, vehicles, etc.	Enhanced greenhouse effect	Altered weather patterns, extreme weather events
Air Pollution	Release of pollutants from industrial and urban activities	Contamination of air	Respiratory illnesses in humans and animals
Water Pollution	Discharge of pollutants into water bodies	Threat to aquatic life, unsafe drinking water	Loss of biodiversity, health risks
Soil Pollution and Erosion	Use of chemical fertilizers and pesticides in agriculture	Soil acidification, erosion, reduced fertility	Farmland degradation, threat to food security
Water Resource Overuse	Excessive irrigation for agriculture	Lowering of water tables, soil salinization	Long-term decline in agricultural productivity
Environmental Regulation	Weaker enforcement in developing regions	Increased pollution and degradation	Higher environmental and health risks

Intensive agriculture, often reliant on chemical fertilizers and pesticides, also poses serious environmental risks. The excessive application of chemicals causes soil acidification and erosion, diminishes soil fertility, and pollutes nearby water bodies through runoff. These effects lead to the degradation of farmland, threatening food security in the long term. Overexploitation of water resources for irrigation has resulted in declining water tables and salinization of soils in many agricultural regions.

Urbanization and Habitat Loss

The world’s urban population has been growing exponentially. While urbanization is associated with economic opportunities and improved access to services, it also generates significant ecological pressure. Cities consume large quantities of natural resources and generate vast amounts of waste and pollution. Rapid urban expansion often encroaches upon natural habitats, leading to fragmentation and destruction of ecosystems.

Loss of habitats results in the displacement or extinction of many species. Fragmented landscapes reduce the ability of animals to migrate, find food, and reproduce, which weakens biodiversity. Furthermore, urban areas often have fewer green spaces, which decreases air quality, reduces opportunities for carbon sequestration, and exacerbates urban heat island effects [5].

Human Role in Ecological Restoration and Sustainability

Despite the many environmental challenges posed by human activity, people are increasingly taking active roles in ecological restoration and conservation. The concept of sustainable development has become central to environmental discourse. It promotes meeting present needs without compromising the ability of future generations to meet theirs.

Sustainable resource management practices aim to balance economic growth with environmental protection. These include adopting renewable energy sources such as solar and wind power, implementing sustainable agricultural

methods (e.g., organic farming, crop rotation), protecting forests, and restoring degraded lands.
Public participation is critical in these efforts. Community-based environmental projects, such as reforestation, wetland restoration, and pollution cleanup initiatives, demonstrate how local involvement can drive positive change. Education and awareness-raising campaigns increase public understanding of environmental issues, empowering people to adopt more eco-friendly lifestyles [6].
Government policies also play a vital role by setting legal frameworks, funding conservation programs, and incentivizing green technologies. International cooperation is necessary to tackle global problems such as climate change, deforestation, and biodiversity loss.

3. Conclusion

In summary, the role of humans in ecology is complex and dual in nature. On one hand, human activities have accelerated environmental degradation, threatening ecosystems and biodiversity. On the other hand, through education, legislation, sustainable practices, and collective responsibility, humans have the capacity to restore ecological balance and promote sustainable development. The future health of the planet depends on the ability of societies worldwide to embrace environmental stewardship. Strengthening ecological awareness, improving environmental governance, and fostering responsible behavior at all levels are imperative. The collaboration of governments, businesses, communities, and individuals will determine whether humanity can live in harmony with nature and secure a sustainable future for generations to come.

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Formatıon of the archıtectural ımage of admınıstratıve buıldıngs ın world practıce

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Abstract: Sustainable architectural design for public buildings is very important for improving the environment, people's health, and the economy. Public buildings have both the chance and the duty to be leaders in the implementation of sustainable techniques since they are very visible and often utilised. This research looks at some of the most important tactics used to design and develop public buildings that are good for the environment. These include passive solar design, energy-efficient HVAC systems, technologies that save water, green roofing, and building materials that have a minimal effect on the environment. The focus is on combining nature-based solutions with user-centred design concepts to make indoor environments better and make communities stronger. The study also shows how sustainable building may help fight climate change and keep ecosystems in balance over the long run. The research shows how public buildings can be great examples of sustainable development and how they can help new policies get started by using case studies and life cycle assessment methods.

Keywords: Sustainable, architectural, climate change, global warming, ecosystem

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1.Introduction

The development of democratic principles, market relations, international relations, the influx of various world brands to Baku have led to the transformation of administrative buildings into business centers of city centers. It is from this perspective that the solution of problems related to the formation of administrative buildings is of particular importance and relevance. Currently, due to the intensity of construction of administrative buildings developing in Baku, we are faced with both location and planning problems. This is an indicator of how relevant the study of administrative buildings is for Baku in our modern era.

The modern city is a synthesis of various systems that are closely interconnected, which form a single structure with architectural and urban planning volumes. The search for modern approaches in the development and formation of a permanent city is always relevant. Administrative buildings are an important element of urban planning [1-5].

2.Experimental detail

Edge, Amsterdam, Netherlands - Deloitte's headquarters in Amsterdam, Edge, is the embodiment of sustainable architecture and energy-efficient design. Having achieved the highest BREEAM rating of its time, it boasts a smart lighting system that adapts to living and daylight levels, an advanced climate control system that uses recycled heat, and solar panels on the roof that generate renewable energy.

Figure 1. Smart village

It is the Smartest Public Building in the World. It knows where you live, what car you drive, who you are meeting today, and how much sugar you have in your coffee. (At least after the next software update.) This is Edge, and it is perhaps the smartest office space ever built (Figure 1).

A day at Edge in Amsterdam starts with a smartphone app developed in collaboration with the building's main tenant, consulting firm Deloitte. You're connected from the moment you wake up. The app checks your schedule, and when you arrive, the building recognizes your car and directs you to a parking spot (Figure 2).

Then the app finds you a desk. Because you don't have one at Edge. Nobody does. Work spaces are based on your schedule: a sit-down desk, a standing desk, a cubicle, a meeting room, a balcony seat, or a "concentration room." No matter where you are, the app learns your lighting and temperature preferences and adjusts the environment accordingly.

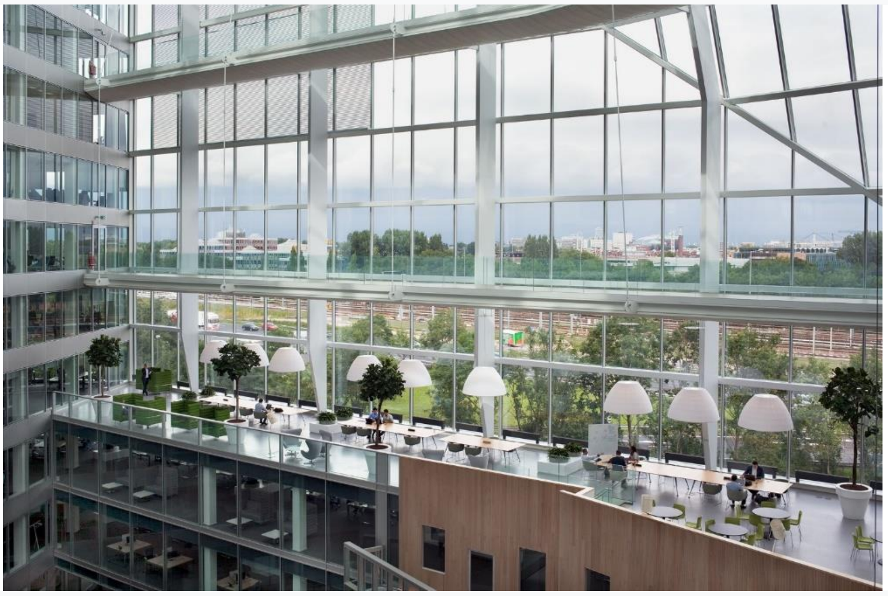

Figure 2. Smart home

According to the British rating agency BREEAM, the Edge is also the world's greenest building, having been awarded the highest sustainability score ever: 98.4 percent. The Dutch have a word for it all: het nieuwe werken, or roughly, the new way of working. It's about using information technology to shape both the way we work and the spaces in which we do it. It's about resource efficiency in the traditional sense – solar panels generate more electricity than the building uses, but it's also about putting people to best use.

The super-efficient LED panels, specially designed by Philips for the Edge, require so little electricity that they can be powered using the same cables that carry data for the Internet. The panels are also packed with sensors—motion, light, temperature, humidity, infrared—creating a "digital ceiling" that wires the building like synapses in the brain. The Edge has about 28,000 sensors.

The atrium is the center of gravity of the Edge solar system. Mesh panels between each floor allow stale office air to escape into the open space, where it rises and is expelled through the roof, creating a natural ventilation loop. Subtle temperature changes and air currents make it feel like the outdoors. Even on a stormy day, the building remains opalescent with natural light and glass angles.

From the outside, the atrium and its iconic sloping roof, which appear to be a wedge cut out of the building, flood the workspaces with daylight and provide a sound buffer from the adjacent highway and train tracks. Each workspace is 7 meters (23 feet) from a window.

"A quarter of this building is not dedicated to desk space, it's a place to meet," says Ron Bakker, architect at Edge at London-based PLP Architecture. "We're starting to see that office space is not about the workspace itself; it's really about creating a working community and having a place where people want to come, where ideas are developed and the future is defined."

About 2,500 Deloitte employees share 1,000 desks. The concept is called hot desking, and it's meant to encourage new connections, casual interactions, and, just as importantly, efficient use of space. Desks are used only when needed. Some of the smaller rooms at Edge have just a chaise longue and a lamp (no desk)—perfect for making phone calls. There are also game rooms and coffee bars with espresso machines that remember how you like your coffee. Massive flat-screens in every corner can be wirelessly synced with any phone or laptop.

Since employees at Edge don't have assigned desks, the lockers serve as a home base during the day. Find a locker with a green light, turn on your badge, and it's yours. Employees are reluctant to stay in the same locker for days or weeks at a time, because part of the het nieuwe werken philosophy is to get people out of their fixed places and rigid mindsets. Deloitte collects gigabytes of data about the interactions between Edge and its employees. A central dashboard tracks everything from energy consumption to coffee machine refills. On days when fewer employees are expected, the entire unit can even shut down, reducing heating, cooling, lighting, and cleaning costs.

Deloitte’s general philosophy with Edge was that anything with a return on investment of less than 10 years is worth trying. The digital ceiling was one of the most expensive innovations; Deloitte wouldn’t disclose the cost, but Erik Ubels, Deloitte’s chief information officer in the Netherlands, says it will take 8.3 years to pay for itself.
There’s no doubt that in the future, all buildings will be connected, both internally and with other buildings, says Ubels. “The multi-billion-dollar question is who will do it. Whoever succeeds will be one of the most successful companies in the world.”
Your smartphone is your passport to Edge. Use it to find your colleagues, adjust the temperature, or manage your gym routine. You can even order a lunch recipe and a bag of fresh ingredients will be waiting for you when the workday is over. All desks are equipped with built-in wireless chargers so your phone can recharge itself.
When you arrive at the Edge, the garage entrance is automated. A camera takes a picture of your license plate, matches it to your employment record, and lifts the door. It even uses LED lights equipped with a garage sensor, which brighten as you approach and dim as you leave. This is the Netherlands, so it’s no surprise that there are separate bike racks and free chargers for electric vehicles. Even the airport taxis in Amsterdam are Teslas. The Edge is equipped with a vast network of two different types of pipes: one for data (ethernet cables) and the other for storing water. Behind each ceiling tile is a large, thin blue pipe that carries water to and from the building’s underground water reservoir for radiant heating and cooling.
During the summer months, the building pumps warm water from more than 400 feet deep in an aquifer beneath the insulated building until it is withdrawn for heating in the winter. According to Robert van Alphen, OVG’s Edge project manager, the system designed for Edge is the world’s most efficient aquifer thermal energy storage system. The south wall is a checkerboard of solar panels and windows. Thick load-bearing concrete helps regulate heat, and deep recessed windows reduce the need for shading, even though they are exposed to direct sunlight. The roof is also covered in panels. The Edge uses 70 percent less electricity than a typical office building, but it wasn’t until OVG installed panels on the roofs of some neighboring university buildings that Edge could boast of generating more energy than it consumes.
Birds, bats, bees and insects. These are the building’s neighbors on the north-facing terrace. OVG worked with Amsterdam officials to create a sustainable vegetation cover that supports beneficial insects throughout the city. Birdhouses and bat boxes are discreetly integrated into the surrounding landscaping. These splayed towers support a variety of solitary bees that buzz about the flowers on the public terrace.

3. Conclusion

Sustainable architectural plans for public buildings include a variety of strategies to reduce environmental impacts, increase energy efficiency, and enhance the well-being of residents and the community. Each approach helps create a more resilient and sustainable future. Public buildings have a unique opportunity and responsibility to lead by example, demonstrating the potential of sustainable architecture to combat climate change and promote harmonious coexistence with the natural world.

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Prediction of the impact of ecological factors on plant biodiversity

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Abstract: Noise stands out as one of the inevitable and widespread environmental problems of modern urban life. Its impact on human health is multifaceted and, in particular, causes cardiovascular diseases, sleep disorders, as well as chronic stress and psychological discomfort. Constant and high levels of background noise have a negative impact on human physical and mental activity, leading to a decrease in the quality of life. In addition, noise is a serious source of danger not only for humans, but also for animals living in nature. The vital functions of animals, such as communication, nutrition and reproduction, are disrupted as a result of noise-induced discomfort, which leads to a disruption of the balance of ecosystems. Technical measures to reduce the negative effects of noise — the introduction of sound insulation systems, the construction of acoustic barriers and the adjustment of sound levels to standards — are of great importance. At the same time, it is necessary to strengthen the legislative framework, noise monitoring and take serious administrative measures against violations in solving the noise problem. On the social side, public education and increased social responsibility are important, as people's individual and collective behavior plays a crucial role in reducing noise. In the long term, public participation and raising social awareness will contribute to effective solutions to the noise problem, making the urban environment more livable and ecologically healthy. Therefore, combating noise should be seen as a complex environmental issue that requires a multidisciplinary approach and systematic measures.

Keywords: Noise, environment, health, ecosystem, management

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1.Introduction

In the modern era, driven by rapid technological advancement, urbanization, and the proliferation of industrial activities, noise pollution has emerged as a critical environmental concern. Unlike traditional forms of pollution that are often visible or measurable through physical residues, noise represents an invisible threat that significantly affects both human health and ecological balance. Persistent and high-intensity noise, primarily originating from transportation systems, manufacturing industries, and densely populated urban environments, not only induces a wide range of physical and psychological disturbances in humans—such as stress, sleep disorders, and hearing impairment—but also disrupts the natural behavior and communication patterns of wildlife, threatening biodiversity and ecological stability. These disruptions can lead to long-term imbalances within ecosystems, particularly affecting species sensitive to acoustic changes in their habitats. Consequently, the investigation of noise pollution's environmental impact and the development of strategic, evidence-based mitigation measures have become essential components of sustainable development. This thesis seeks to explore the multifaceted effects of noise on the environment, with a specific focus on its implications for human health and natural systems, highlighting the urgent need for comprehensive noise management policies and innovative urban planning solutions that prioritize acoustic well-being alongside economic growth.

In today's world, rapid technological advancement, accelerated industrialization, and intensified urbanization have significantly increased the impact of human activities on the environment. These processes have brought numerous ecological challenges to the forefront, among which noise pollution occupies a particularly important place. Noise is not only one of the physical pollutants affecting the environment, but it also represents a complex and multifaceted ecological issue with adverse effects on both social and biological systems.

This problem is especially pronounced in large urban areas, industrial zones, and transportation hubs, where high levels of noise pollution pose serious threats to both the quality of human life and the sustainability of natural ecosystems. The pervasive nature of noise in these environments makes it a critical environmental concern requiring urgent attention.

The sources of noise pollution are diverse and numerous. These include the movement of transportation vehicles such as cars, buses, trains, and airplanes, the operation of industrial facilities, ongoing construction activities, the functioning of railways and airports, as well as noise generated from household and commercial establishments. Each of these sources produces sound waves with varying intensity and characteristics, making the overall impact of noise pollution on the environment highly complex [1-6].

2.Experimental detail

The consequences of noise pollution are profound, particularly from the perspective of human health and biodiversity. Long-term exposure to high-intensity noise has been linked to a wide range of health disorders. For instance, cardiovascular diseases, high blood pressure, sleep disturbances, chronic stress, and psychological disorders are among the most commonly observed health problems associated with noise pollution.

Table 1. Key Impacts of Noise Pollution

Impact Area	Examples of Effects
Human Health	- Cardiovascular diseases - High blood pressure - Sleep disturbances
Cognitive Function	- Decreased attention - Memory impairment - Reduced productivity
Social Well-being	- Increased stress and anxiety - Social withdrawal - Lower quality of life
Wildlife & Ecology	- Disrupted communication and mating - Habitat abandonment - Declining species

Scientific research has demonstrated that constant exposure to noise can impair cognitive functions such as attention and memory, reduce work efficiency, and contribute to mental fatigue. In addition, noise pollution disrupts social relations by increasing interpersonal tensions, discouraging social participation, and ultimately deteriorating the overall quality of life. These psychosocial effects undermine societal well-being and threaten social cohesion.

Moreover, the ecological impacts extend to wildlife and natural habitats, where excessive noise can interfere with animal communication, mating behaviors, navigation, and predator-prey interactions, leading to a decline in biodiversity. Therefore, noise pollution must be recognized not just as an urban inconvenience, but as a significant environmental issue with wide-reaching implications for both human and ecological health.

Noise pollution poses significant and far-reaching threats not only to human health and well-being but also to biological ecosystems. The effects of environmental noise on wildlife are profound and multifaceted. In natural habitats, many animal species rely on sound for essential behaviors such as communication, hunting, feeding, and reproduction. Excessive noise can disrupt these behaviors, resulting in serious ecological consequences.

Particularly in areas with high levels of anthropogenic noise—such as urban centers, industrial zones, and transportation corridors—wildlife is subjected to constant acoustic stress. For many species, these disturbances can lead to behavioral changes, habitat abandonment, and impaired reproductive success. In extreme cases, populations of certain species may decline as individuals fail to adapt to the chronically noisy conditions.

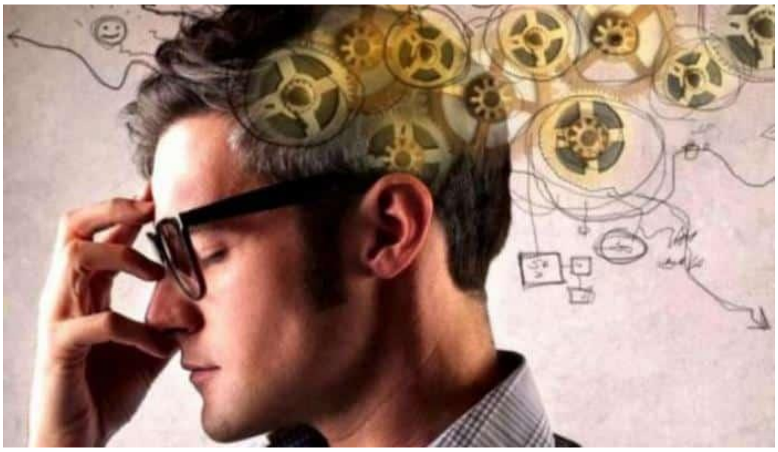

Figure 1. The impact of noise on humans

This disruption contributes to a broader decline in biodiversity, disturbs ecological balance, and reduces ecosystem resilience. Ultimately, such degradation compromises ecological security, leading to long-term consequences for both natural environments and the human societies that depend on them.

In response to the growing threat of noise pollution, a wide range of modern and integrated measures have been implemented across various domains. From a technical perspective, innovative soundproofing and noise reduction technologies are increasingly being used at the source. These include advanced insulation materials, quieter machinery designs, and acoustic barriers designed to prevent the spread of noise in surrounding areas. Ensuring that noise levels comply with established environmental standards, along with continuous monitoring, is also a key aspect of these technical interventions.

Urban planning and land-use strategies play a vital role in mitigating noise impacts as well. The creation and expansion of green spaces, urban forests, and buffer zones serve as natural sound absorbers and contribute to improved acoustic environments. Zoning regulations that spatially separate residential, recreational, and educational areas from high-noise sources help minimize direct exposure to harmful noise levels. Additionally, the strategic positioning of infrastructure and transportation networks can further mitigate noise distribution across urban landscapes.

Legislation and governance frameworks are equally essential for controlling noise pollution. The establishment of comprehensive legal standards, the development of enforceable noise regulations, and the imposition of administrative penalties for violations create a regulatory environment that promotes compliance and accountability. Effective noise management requires coordination between government bodies and private sector stakeholders to ensure consistent enforcement and policy implementation.

On a societal level, raising public awareness about the adverse effects of noise pollution is critical. Educational campaigns targeting behavioral change, both at individual and community levels, are necessary to foster a culture of responsibility toward noise management. Mass media platforms—such as social media, television, radio, and digital news outlets—serve as powerful tools for disseminating information and encouraging public engagement.

Table 2. Impacts of Noise Pollution and Mitigation Strategies

Category	Impacts of Noise Pollution	Mitigation Strategies
Human Health	- Cardiovascular diseases - High blood pressure - Sleep disturbances - Chronic stress and anxiety - Reduced cognitive performance	- Use of soundproofing materials - Health regulations and noise exposure limits
Social Effects	- Increased interpersonal tension - Social withdrawal	- Public awareness campaigns - Promotion of quiet zones

	- Decreased quality of life	- Urban green areas
Biological Ecosystems	- Disruption of animal communication - Interference with feeding and mating - Habitat abandonment - Population decline	- Creation of buffer zones - Conservation of habitats - Noise monitoring systems
Urban Environment	- Elevated noise levels in residential and public areas - Acoustic discomfort	- Acoustic barriers - Strategic urban planning - Zoning regulations
Legislation & Policy	- Inadequate regulation leads to uncontrolled noise levels	- Enforcement of noise standards - Monitoring and penalties for violations
Technology Solutions	- Persistent noise from transportation, industry, and construction	- Development of quieter engines and machinery - Implementation of noise control tech

Increasing environmental consciousness among citizens and promoting noise-responsible behavior can lead to a substantial reduction in noise pollution over time. Such efforts not only contribute to a healthier acoustic environment but also enhance the overall quality of urban life and support the broader goals of sustainable development and ecological well-being.

3. Conclusion

In conclusion, noise pollution remains a multifaceted and complex challenge for modern society. Its pervasive nature and harmful impacts pose significant concerns across various domains, including public health, ecological stability, and urban quality of life. The wide range of its sources—from transportation systems and industrial activities to construction and daily human behavior—makes it one of the most difficult environmental issues to control.

The severity of its consequences demands a coordinated and integrated approach to management. Technological innovations, such as sound insulation systems and quieter machinery, offer effective ways to reduce noise at the source. Meanwhile, robust legislative frameworks are essential to establish clear noise standards, enforce compliance, and impose sanctions for violations. At the same time, public education and awareness campaigns play a crucial role in fostering responsible attitudes and encouraging behavioral change among individuals and communities.

Addressing noise pollution effectively requires the active participation of all segments of society, including governments, businesses, civil organizations, and citizens. This collective responsibility is fundamental to building an environmentally conscious culture that prioritizes both human well-being and ecological sustainability.

Ultimately, the integration of technical, regulatory, and social strategies forms the cornerstone of modern efforts to mitigate the impact of noise pollution. Such a comprehensive approach is vital not only for reducing environmental noise levels but also for promoting long-term sustainable development, protecting biodiversity, and enhancing the overall quality of life in urban environments.

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Ecological problems of modern cities

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Abstract: Along with the rapid development of modern cities, significant environmental challenges have arisen. Industrialization, increased transportation, and the fast-growing urban population have led to problems such as air and water pollution, increased waste generation, and the reduction of green spaces. These issues negatively affect not only the environment but also human health, causing a range of problems from allergies to chronic respiratory diseases. To address these challenges, large-scale state-level measures are essential. Improving environmental legislation, managing waste properly, adopting alternative energy sources, and implementing technological innovations play a crucial role in this effort. However, these actions alone are not enough. Public awareness, promoting sustainable lifestyles, and fostering a sense of individual and collective responsibility are equally important. For cities to become ecologically sustainable, the responsible behavior of every citizen is vital. People should adopt daily habits that conserve water, energy, and natural resources, as well as practice proper recycling and waste sorting. Only through cooperation between the government, society, and individuals can cities develop in a way that does not harm the environment, ensuring a healthier and more sustainable future for all.

Keywords: Environmental problems, urbanization, environment, sustainable development, public awareness

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1.Introduction

One of the most pressing issues of the modern era is the environmental tension arising amid the rapid acceleration of urbanization. The expansive growth of urban areas, coupled with intensified industrialization, an increase in the number of vehicles, and the significant reduction of green spaces, has led many major cities to face severe ecological challenges. Problems such as air and water pollution, escalating noise levels, improper waste management, and a decline in biodiversity directly affect the health and quality of life of urban residents. These environmental stresses not only threaten natural ecosystems but also impose serious social and economic consequences.

The rapid pace of urbanization often outstrips the capacity of cities to manage resources sustainably, leading to degradation of environmental quality. Air pollution, largely driven by industrial emissions and traffic congestion, contributes to respiratory diseases and other health problems among city dwellers. Water pollution from untreated sewage and industrial discharge compromises drinking water supplies and harms aquatic life. Additionally, noise pollution creates chronic stress and negatively impacts mental well-being. The mismanagement of solid waste results in land and groundwater contamination, while the loss of green areas diminishes the natural ability of cities to regulate temperature, filter air, and support wildlife.

Given these pressing issues, preserving ecological balance and integrating sustainable urban planning strategies have become paramount priorities. Effective urban planning must focus on creating resilient cities that harmonize economic growth with environmental protection. This includes the development and implementation of eco-friendly technologies, the promotion of renewable energy, enhancement of public transportation, and the conservation and expansion of urban green spaces. Such measures are essential for mitigating the negative impacts of urbanization and ensuring that cities remain healthy and livable environments.

This thesis aims to analyze the main ecological problems confronting modern cities by exploring their root causes and consequences. Furthermore, it seeks to identify practical and innovative solutions to these challenges by reviewing current strategies and proposing sustainable pathways forward. Through a comprehensive examination of the interplay between urban development and environmental health, the study will contribute to the ongoing dialogue on how to build cities that are not only economically vibrant but also ecologically sustainable and socially inclusive.

The rapid development of modern cities, while driving significant socio-economic progress, has simultaneously caused considerable harm to the environment. This environmental damage stems from several key factors, including the intensive operation of industrial enterprises, increased traffic congestion, inefficient use of energy resources, and a sharp rise in the urban population. These combined processes have given rise to a wide range of ecological problems that threaten both nature and human well-being [1-6].

2.Experimental detail

One of the most widespread and pressing environmental issues in cities is air pollution. Emissions from automobiles, industrial waste, and energy production release harmful substances into the atmosphere, which adversely affect human health by increasing the incidence of respiratory diseases such as asthma, bronchitis, and other chronic conditions. Furthermore, the rising concentration of carbon dioxide and other greenhouse gases contributes to global climate change, leading to altered microclimates within urban areas. These urban heat islands exacerbate temperature extremes, negatively impacting the comfort and health of city residents, while also stressing urban infrastructure and ecosystems.

Water pollution constitutes another significant environmental challenge. Industrial facilities and residential areas often discharge untreated or inadequately treated wastewater into rivers, lakes, and other water bodies. This contamination degrades water quality, reduces available sources of safe drinking water, and damages aquatic ecosystems that are vital for maintaining biodiversity and natural water purification processes. Polluted water sources pose direct health risks to the population and undermine sustainable development efforts [2].

Table 1. Key ecological measures and their expected impacts in urban environmental protection

Ecological Measure	Description	Expected Impact
Legislation and Regulation	Development and enforcement of environmental protection laws by governments and local authorities	Reduction of pollutants in industry and transportation sectors; compliance with environmental standards
Waste Treatment Technologies	Installation of filtration systems in industrial enterprises and wastewater treatment plants	Decrease in air and water pollution; protection of ecosystems
Development of Public Transport	Modernization and expansion of public transportation systems in cities	Reduction of vehicle emissions and traffic congestion
Alternative Energy Sources	Use of clean energy sources such as solar, wind, and hydropower	Reduction of carbon emissions; mitigation of climate change
Expansion of Green Spaces	Tree planting campaigns, establishment of parks, and preservation of existing green areas	Air purification, reduction of urban heat island effect, and preservation of biodiversity
Environmental Awareness	Educating the public about environmental issues and promoting sustainable lifestyles	Increased environmental responsibility and stronger individual and collective efforts
“Smart City” Technologies	Implementation of resource management, environmental monitoring, and energy-saving technologies	More efficient resource use and enhanced urban sustainability

Additionally, the improper management of solid municipal waste presents a critical problem. Many cities struggle with insufficient waste collection systems, leading to illegal dumping sites and unregulated landfills. These practices disrupt ecological balance, causing soil contamination and groundwater pollution through the leaching of hazardous substances. The resulting environmental degradation creates favorable conditions for the spread of infectious diseases and poses serious risks to public health.

Moreover, the reduction of green spaces—commonly referred to as the "concretization" of cities—due to urban expansion and deforestation weakens the natural ability of the environment to filter pollutants from the air. Trees and vegetation play an essential role in improving air quality, regulating temperature, and maintaining ecological balance within urban landscapes. Their loss limits the habitats available for wildlife, reduces biodiversity, and diminishes the overall resilience of city ecosystems. This shrinkage of green areas also negatively affects the mental and physical well-being of urban residents by depriving them of natural spaces that provide recreation and stress relief [3].

To mitigate these environmental challenges, a multifaceted approach is required, combining technological innovations, effective urban planning, strong legislative frameworks, and active public participation. Only through coordinated efforts can modern cities transform into sustainable environments that support both economic growth and ecological preservation, ensuring a healthier and more livable future for their inhabitants.

To address these pressing environmental problems, a variety of ecological measures have been implemented worldwide. Foremost among these efforts is the development and enforcement of environmental protection legislation by governments and local authorities. Such laws aim to regulate pollution levels, set standards for waste disposal, and promote sustainable resource management. Strict legal frameworks ensure that industries and urban activities comply with environmental norms, helping to reduce harmful emissions and prevent further ecological degradation.

In tackling air and water pollution, advanced waste treatment technologies are increasingly adopted. Industrial enterprises are required to install filtration and purification systems that significantly decrease the release of toxic substances into the atmosphere and water bodies. Wastewater treatment plants help clean domestic and industrial effluents before they are discharged, thus preserving water quality and protecting aquatic ecosystems. Moreover, continuous monitoring and stricter penalties for violations act as deterrents against environmental neglect [4].

Simultaneously, efforts to reduce carbon emissions are gaining momentum through the promotion of public transportation systems and the integration of alternative energy sources. Expanding and modernizing public transit helps decrease the reliance on private vehicles, thereby reducing traffic congestion and vehicle emissions. At the same time, investments in renewable energy—such as solar, wind, and hydropower—contribute to lowering greenhouse gas emissions from fossil fuel combustion. This transition to clean energy sources is essential for mitigating climate change and improving urban air quality.

Figure 1. Environmental problems

Urban greening initiatives also play a vital role in improving the environmental conditions of cities. Tree planting campaigns, the creation of new parks, and the preservation of existing green spaces help restore ecological balance, enhance biodiversity, and improve residents' quality of life. Green areas act as natural air filters, reduce urban heat islands, and provide recreational spaces that promote mental and physical well-being. Alongside these efforts, ecological education programs raise public awareness about environmental challenges and encourage sustainable behavior among citizens [5].

Table 2. Ecological Measures Addressing Urban Environmental Challenges

Ecological Measure	Description	Role and Impact
Environmental Legislation	Development and enforcement of pollution regulations, waste disposal standards, and resource management laws	Ensures industries and urban activities comply with environmental norms; reduces harmful emissions and ecological degradation
Waste Treatment Technologies	Installation of filtration systems and wastewater treatment plants	Reduces toxic emissions and water pollution; protects ecosystems
Promotion of Public Transportation	Expansion and modernization of urban transit systems	Decreases reliance on private vehicles; reduces traffic congestion and vehicle emissions
Alternative Energy Sources	Use of renewable energy such as solar, wind, and hydropower	Lowers greenhouse gas emissions; mitigates climate change
Urban Greening Initiatives	Tree planting, creation, and preservation of parks and green spaces	Restores ecological balance; enhances biodiversity; reduces urban heat island effect; improves quality of life
Ecological Education Programs	Public awareness campaigns and sustainability promotion	Encourages environmentally responsible behavior among citizens
Smart City Technologies	Implementation of smart grids, sensor networks, and data-driven resource management	Enables efficient resource use, real-time pollution monitoring, and proactive environmental management

In addition, the adoption of "smart city" technologies offers promising solutions to urban environmental problems. These technologies enable efficient resource management, real-time pollution monitoring, and optimized energy consumption, contributing to the creation of more sustainable and resilient urban environments. Smart grids, sensor networks, and data-driven decision-making help cities respond proactively to environmental issues and improve overall quality of life [6].

Overall, the environmental challenges facing cities are complex and multifaceted, requiring coordinated actions at multiple levels. Their resolution depends not only on the initiatives of governments and international organizations but also on the active participation of civil society, the business sector, and individual citizens. Sustainable urban development can only be achieved through the collective efforts of all stakeholders, fostering a culture of responsibility and cooperation to protect the environment for present and future generations.

3. Conclusion

Addressing environmental problems goes far beyond merely implementing administrative and technological measures. While regulations and innovative technologies are crucial components of the solution, raising public awareness and fostering a deeper sensitivity toward ecological issues among individuals hold equally significant importance. It is essential that people develop a stronger understanding of how their daily actions impact the environment and embrace a more responsible attitude toward natural resources and sustainability.

At the same time, promoting a sustainable and environmentally conscious lifestyle must become a central priority in efforts to combat ecological challenges. This includes encouraging behaviors such as reducing waste, conserving water and energy, choosing eco-friendly products, and supporting green initiatives within communities. Educational programs, media campaigns, and community involvement play a pivotal role in cultivating this mindset and motivating citizens to take an active part in environmental protection.

Only through the combined efforts of governments, businesses, civil society, and each individual can we create a cultural shift toward sustainability. When these values become deeply ingrained in society, cities can transform into healthy, livable, and ecologically sustainable spaces. This holistic approach not only safeguards the environment but also improves the quality of life for present and future generations, ensuring that urban development proceeds in harmony with the natural world.

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Prediction of the impact of ecological factors on plant biodiversity

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Abstract: This article goes into great detail on the architectural design of administrative buildings, focussing on how they are planned, what major architectural characteristics they need, and how they will be used. The research stresses the relevance of user-centred design and spatial organisation. It shows how the way architectural parts are arranged may have a direct influence on how well a building works and how easy it is to use. The article shows how diverse architectural styles and techniques have changed throughout time to meet the demands of different cultures, environments, and governments by comparing examples from different nations and times. The chosen case studies show how to construct public buildings in the best way, giving architects, planners, and researchers useful information. In the end, our study helps us better understand how careful design of buildings may help institutions do their jobs while also making them more comfortable, accessible, and environmentally friendly.

Keywords: administrative building, impact, color, interior elements.

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1.Introduction

Administrative buildings are important centers of government administration and public services. The design of these buildings is carefully planned to meet functional and aesthetic requirements. The layout of the architectural elements of administrative buildings is very important in terms of their use and effectiveness. In this section, we will examine this important topic and explain the basic principles and design processes of the architectural elements of administrative buildings.

The design and layout of administrative buildings do not only consist of technical and functional aspects. Also, these buildings, as symbols of society and the state, must be aesthetically attractive and effective. For this purpose, architects and designers create modern and functional buildings by combining various architectural elements and design principles.

Interior solutions for administrative buildings consist of various elements according to their functionality, design style and intended use. Each of these elements plays a major role in the interior space of the building, both aesthetically and practically [1-5].

2.Experimental detail

Below is an analysis of the interior elements of administrative buildings:

1. Planning and Space Organization

- Division into Different Zones: Interior design should clearly separate work areas (management offices, meeting rooms) and public areas (lobbies, waiting rooms).

- Open Spaces: Open-plan office zones designed for collaboration and communication are prevalent in modern buildings.

2. Wall and Ceiling Design

- Wall Materials: Acoustic panels are used to increase sound insulation. Decorative wall coverings provide the visual appeal of the space from an aesthetic point of view.

- Ceiling Design: Lighting systems and acoustic panels placed on the ceilings combine functionality and design.

3. Lighting Elements

- Natural Lighting: Large windows and glass facades increase the efficiency of lighting and reduce energy consumption.

- Artificial Lighting: LED technology lamps are used to illuminate the workplace well and ensure energy savings.

4. Furniture and Equipment

- Ergonomic Furniture: Ergonomic chairs and tables are essential for employee comfort. Modern, multifunctional furniture supports the aesthetic appearance of the space.

- Technological Equipment: Equipment such as projectors, smartboards, workstations help to carry out the work process efficiently.

5. Color Palette

- Psychological Effect of Colors: Neutral and calming colors (e.g. white, gray, beige) are considered ideal for concentration and productivity. Colors can also emphasize brand identity in the interior.

6. Flooring Materials

- Practical Materials: Durable, easy-to-clean materials are used for flooring (e.g. laminate, ceramic tiles or carpeting).
- Sound Insulation: The use of carpeting and special materials reduces sound reflection.

7. Decorative Elements

- Artwork and Decoration: Pictures, sculptures and other decorative elements are used to enrich the interior and make the work environment more attractive.
- Plants and Greenery: Various green plants and flowers are considered an integral part of the interior to create a sense of naturalness.

8. Security and Technical Elements

- Control Systems: Cameras and entry-exit control systems are integrated into the interior design for security purposes in administrative buildings.
- Ventilation and Climate Control Systems: Modern ventilation and heating-cooling systems are applied to control the climate and create a comfortable environment.

The layout of the architectural elements of administrative buildings should be carefully considered to meet functional and aesthetic requirements. The design of these buildings is planned in accordance with the functions intended for their use, and at the same time, it is aimed to be aesthetically attractive. A reasonable layout ensures that administrative buildings operate effectively and efficiently.

The colors used in the interior solutions of administrative buildings aim to increase the functionality, aesthetic appeal and productivity of the space. The correct selection and use of colors can significantly affect the atmosphere of the space and the mood of the employees. Below is information about the most commonly used colors in the interior solutions of administrative buildings and their effects:

1. White and Light Tones

- Effect: Creates a feeling of cleanliness, sincerity and spaciousness. These colors help the space appear brighter and more spacious.
- Areas of Use: Suitable for office areas, meeting rooms and sanitary facilities.

2. Blue

- Effect: Creates a peaceful and calm atmosphere, increases concentration and productivity.
- Areas of Use: Suitable for meeting rooms, private offices and work areas.

3. Green

- Effect: Creates a natural and comfortable feeling, reduces stress and brings calm.
- Areas of Use: Ideal for relaxation areas, canteens and classrooms.

4. Yellow

- Effect: Creates a feeling of energy and happiness, encourages creative thinking.
- Areas of Use: Suitable for idea rooms and creative work areas.

5. Orange

- Effect: Creates a warm and inviting atmosphere, increases employee energy and interaction.
- Areas of Use: Ideal for social areas and dining areas.

6. Red

- Effect: Creates a sense of energy and excitement, used to focus attention. However, it can increase stress if used too much.
- Areas of Use: Used as an accent color, suitable for entrance areas and living rooms.

7. Gray and Neutral Tones

- Effect: Creates a professional and serious atmosphere, creates balance when combined with other colors.
- Areas of Use: Suitable for office areas and meeting rooms.

8. Brown and Earth Tones

- Effect: Creates a sense of stability and reliability, helps the space look more natural.
- Areas of Use: Ideal colors for office spaces and kitchens.

9. Pastel Tones

- Effect: Creates a soft and calm atmosphere, reduces stress and provides comfort.
- Areas of Use: Suitable for recreation areas, classrooms and private offices.

The choice and use of colors play an important role in ensuring that administrative buildings meet functional and aesthetic requirements. The bright colors help to enhance the atmosphere of the space, the mood of employees and their productivity. It is important to choose colors that suit the specific needs and use of each space.

3. Conclusion

The article provides extensive information on the design processes of administrative buildings, the architectural elements used, and the functional requirements of these buildings. It also presents examples from different countries and periods, showing how different architectural styles and approaches are applied.

The layout of the architectural elements of administrative buildings is essential for their effective and efficient operation. Each element of these buildings must be carefully considered and must be in accordance with the needs of the users. The examples and studies presented in the book will provide readers with in-depth knowledge and new perspectives in this field.

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Climate Control Systems for Buildings and Infrastructure in Urban Areas

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Abstract: The rapid progression of climate change presents significant challenges in urban areas, demanding innovative approaches for sustainable development. Urban heat islands (UHI), unpredictable weather patterns, and escalating energy demands are among the critical issues placing immense pressure on building infrastructure while reducing indoor comfort. These challenges underscore the need for advanced solutions to ensure that urban spaces remain livable and energy-efficient. Climate control systems have emerged as a key component of sustainable urban infrastructure, particularly when combined with cutting-edge technologies such as Programmable Logic Controllers (PLCs). Initially developed for industrial automation, PLCs have evolved to become integral to building automation systems, thanks to their ability to perform real-time monitoring and adaptive responses to fluctuating environmental conditions. Their role in optimizing energy usage and maintaining indoor comfort makes them an indispensable tool in the fight against climate change. PLCs facilitate seamless integration of various subsystems, including heating, ventilation, and air conditioning (HVAC), lighting, and renewable energy sources, enabling efficient management of energy resources. By leveraging real-time data, these systems dynamically adjust to environmental changes, significantly reducing energy wastage. Additionally, their versatility in automation and predictive maintenance enhances the reliability and sustainability of building operations. This article delves into the integration of PLC programming within climate control systems, showcasing how these technologies can transform urban infrastructure to meet the growing demands of energy efficiency, comfort, and sustainability.

Keywords: Climate Control Systems, Programmable Logic Controllers (PLCs), Building Automation, Energy Efficiency, Urban Heat Island (UHI) Effect

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1.Introduction

Cities today face a range of climate-related challenges, from urban heat islands (UHI) to erratic precipitation patterns and more frequent extreme weather events. In rapidly growing urban centers like Baku, Azerbaijan, the effects of climate change are particularly noticeable. Heatwaves, higher temperatures, and fluctuating humidity levels are putting immense pressure on urban infrastructure and building systems.

Heatwaves and Rising Temperatures: The rise in global temperatures is making it more difficult to maintain comfortable indoor environments without over-relying on air conditioning and other cooling systems. Buildings that were not designed with extreme heat in mind are now vulnerable to thermal discomfort, which impacts both occupants and energy consumption [9, 10].

Urban Heat Island Effect: Urban areas tend to be warmer than their rural surroundings due to the concentration of human activity, buildings, roads, and energy consumption. This phenomenon, known as the Urban Heat Island (UHI) effect, exacerbates the impact of heatwaves, leading to higher energy demands for cooling, poorer air quality, and increased public health risks.

Irregular Weather Patterns: As weather patterns become more unpredictable, buildings must be able to adapt to sudden changes in temperature, humidity, and wind. The traditional approaches to climate control often lack the flexibility to respond to these dynamic conditions efficiently.

Effective climate control systems within buildings are key to combating these challenges, ensuring thermal comfort, air quality, and energy efficiency while reducing the environmental impact of high energy consumption [12, 14].

The Role of PLC Programming in Climate Control Systems

Programmable Logic Controller (PLC) is a digital computer used for automation and control purposes. Originally designed for industrial applications, PLCs are now used in a wide variety of systems, including building automation. They operate by receiving input from sensors, processing that data using pre-programmed logic, and then issuing commands to control devices such as heating, ventilation, and air conditioning (HVAC) systems, lighting systems, fans, and more. PLCs are an ideal solution for climate control systems in buildings due to their versatility, reliability, and ability to integrate with various sensors and control devices [4, 6, 7]. Their main functions include:

Real-Time Control: PLCs process data in real-time, allowing them to adjust building systems dynamically based on immediate environmental conditions.

Automation: PLCs can automate the operation of multiple systems, reducing the need for manual intervention and ensuring optimal performance even during extreme weather events.

Energy Efficiency: By integrating data from temperature, humidity, and occupancy sensors, PLC systems can optimize the use of energy-consuming systems, reducing waste and improving overall efficiency.

Through PLC programming, building managers can automate and optimize climate control systems to ensure that temperature, humidity, and air quality are kept within ideal ranges, minimizing the impact of external weather conditions on building occupants [4, 12].

Key Components of PLC-Driven Climate Control Systems

1. Temperature and Humidity Control

One of the primary functions of PLC-controlled climate systems is maintaining optimal temperature and humidity levels. In a building, environmental comfort depends on more than just keeping the temperature at a set level; managing the relative humidity is also critical to ensure the indoor air quality and comfort of occupants.

Temperature Sensors: PLC systems use temperature sensors to continuously monitor the internal and external temperatures of a building. This data is then fed into the PLC, which processes the information and adjusts the operation of HVAC units (heating, ventilation, and air conditioning) accordingly. For instance, during a heatwave, a PLC can activate the air conditioning system before the temperature reaches uncomfortable levels.

Temperature sensors are a vital component in automation systems for building climate control, industrial processes, and a wide range of other applications. In PLC programming, temperature sensors can be used to monitor the temperature of an environment or process, and the PLC can then take actions based on that data, such as turning on or off HVAC systems, controlling heating/cooling elements, or sending alerts when temperature thresholds are exceeded [5].

Types of Temperature Sensors Used in PLC Systems

Thermocouples: Measure temperature by generating a voltage that varies with temperature.

Common in high-temperature environments.

Output is often in millivolts, so a signal conditioner may be needed before feeding the signal to a PLC.

RTDs (Resistance Temperature Detectors): Use the principle that the resistance of certain materials (typically platinum) changes with temperature.

Output resistance is typically converted into a voltage signal for the PLC.

Thermistors: Similar to RTDs but use a different material (usually ceramic) that changes resistance with temperature.

Have a non-linear resistance-temperature relationship.

Analog Temperature Sensors: These sensors output a continuous voltage or current proportional to the temperature (e.g., 0-10V, 4-20mA).

Digital Temperature Sensors: Provide temperature data in a digital format, often through protocols like I2C or Modbus.

More straightforward to interface with PLCs that have digital communication ports.

2.Experimental detail

Input Channel: Analog input configured to read 4-20mA (which the PLC will interpret as a range of 0°C to 100°C).

Control Output: A cooling fan or heater connected to an output relay or contactor.

Set Points: Turn on cooling at 25°C, turn off cooling at 23°C.

Steps for PLC Temperature Control Programming: Convert Sensor Input to Temperature Value

The PLC’s analog input channel needs to convert the incoming 4-20mA signal to a temperature reading. Depending on the PLC and its software, this may require scaling the analog input.

For example, the 4-20mA current needs to be scaled to the temperature range of 0°C to 100°C. The scaling formula can be written as:

$$Temperature\ (C^{O}) = \frac{(Current\ (mA) - 4)}{16} X\ 100$$

Set Temperature Thresholds

We want to turn on the cooling system if the temperature exceeds 25°C, and turn it off if it drops below 23°C.

PLC Program Logic:

Ladder Logic Example:

|----| Temperature >= 25°C |----| Cooling On |

|----| Temperature <= 23°C |----| Cooling Off|

When the temperature exceeds 25°C, the cooling system is turned **on**.
When the temperature drops below 23°C, the cooling system is turned **off**.

Detailed Steps for PLC Ladder Logic Program:
Scaling Analog Input:
The PLC's analog input (AI1) will receive the 4-20mA signal. We will need to scale this input to match the temperature values.
Let's assume the PLC has a function to convert the 4-20mA signal to a temperature value, so:
When AI1 = 4mA, Temperature = 0°C
When AI1 = 20mA, Temperature = 100°C
If the input range is scaled (e.g., via PLC software configuration), the program can then convert the analog input to the corresponding temperature value.
Create a Comparison Block:
In the PLC programming software (such as RSLogix 5000, TIA Portal, or CODESYS), create comparison blocks to compare the temperature to the set points (25°C and 23°C).
Example comparison logic:
Temperature >= 25°C (for cooling on)
Temperature <= 23°C (for cooling off)
Control Output (Cooling System):
Based on the temperature comparison, we can control the output. Let's assume the cooling system is connected to a relay (let's say O:0/1 for cooling system).
If the temperature is greater than or equal to 25°C, the output (O:0/1) will turn on to activate the cooling system.
If the temperature is less than or equal to 23°C, the output (O:0/1) will turn off to deactivate the cooling system.

Ladder Logic for Output Control:

|----| Temp >= 25°C |---(Cooling On)---|
|----| Temp <= 23°C |---(Cooling Off)---|

Sample Ladder Logic Code:
Temperature Conversion (using an appropriate scaling function or analog-to-digital conversion block):
In a real-world PLC system, the 4-20mA signal is converted to a digital value using a scaling function. For instance, the PLC might have an instruction that scales the 4-20mA signal to a temperature range. This will look something like:
Scale (4-20mA Signal to Temperature) -> Temperature (0°C to 100°C)
Temperature Control Logic:
|----| Compare Temperature >= 25°C |---(Set Cooling On)
|----| Compare Temperature <= 23°C |---(Set Cooling Off)
In this example, the PLC logic reads the scaled temperature and compares it with the set points (25°C and 23°C).
Based on the result of the comparison, the cooling system is activated or deactivated.
Example PLC Programming in Structured Text (ST):
Structured Text is another programming language supported by many PLCs. Below is an example of Structured Text (ST) programming for a temperature sensor:
In this code:
AI1 represents the analog input from the temperature sensor (scaled from 4-20mA to temperature).
The cooling system is controlled by setting the cooling status variable to TRUE (on) or FALSE (off) based on the temperature thresholds.
Humidity Sensors: Humidity sensors are equally important in climates where excess moisture or dryness can affect both comfort and health. PLCs use real-time humidity data to control dehumidifiers or humidifiers, ensuring the environment remains comfortable and free of excessive moisture or dryness.
By integrating both temperature and humidity control into a PLC-based system, buildings can adapt to changing environmental conditions and maintain an optimal indoor climate at all times.

```
// Define temperature input from the analog sensor
VAR
    temp_in : REAL;     // Temperature value from the sensor (in Celsius)
    cooling_status : BOOL;  // Status of the cooling system
END_VAR

// Scale analog input (4-20mA to 0-100°C)
temp_in := (AI1 - 4) / 16 * 100;

// Control logic for cooling system
IF temp_in >= 25.0 THEN
    cooling_status := TRUE;   // Turn on cooling system
ELSIF temp_in <= 23.0 THEN
    cooling_status := FALSE;  // Turn off cooling system
END_IF
```

Figure 1. Structured Text (ST) programming for a temperature sensor

2. Automated HVAC System Control

HVAC systems are among the largest energy consumers in buildings, particularly in regions with extreme weather. PLCs help reduce energy consumption by ensuring that HVAC systems are only running when necessary and are operating at peak efficiency [5].

Heating and Cooling Scheduling: Using data from sensors and external weather forecasts, PLCs can schedule heating and cooling activities based on real-time conditions. For example, the system might lower heating during the night when the outside temperature drops and increase cooling during the day when heat rises.

Energy Management: A key benefit of PLC-based systems is their ability to optimize energy consumption. For example, during a heatwave, the PLC can regulate cooling units by adjusting settings or activating certain systems only when the temperature exceeds a set threshold. In addition, if the system detects that certain rooms or zones are unoccupied, it can reduce or turn off cooling or heating in those areas [9, 11].

Integration with Smart Devices: PLCs can be integrated with smart thermostats, lighting, and ventilation systems, allowing for complete automation. For example, PLCs can adjust not just the temperature, but also the intensity of lighting and ventilation, further reducing energy consumption [1, 13].

3. Zoning and Individual Control

In larger buildings, the implementation of zoning allows for individualized climate control. Instead of treating the entire building as one homogeneous space, PLC systems can divide the building into zones that are conditioned independently based on usage patterns and occupancy [4].

Occupancy Sensors: Occupancy sensors feed data into the PLC, which then adjusts the temperature in specific zones based on how many people are present. In a large office building, for example, PLCs can reduce cooling in empty rooms while ensuring that occupied spaces remain comfortable.

Smart Ventilation: By controlling airflow and ventilation systems for each zone independently, PLCs can adjust air quality, oxygen levels, and temperature for each area. This provides maximum comfort and efficiency by ensuring that energy is not wasted in underused spaces.

4. Predictive Maintenance and Fault Detection

A critical feature of PLC-based systems is their ability to perform predictive maintenance. By continuously monitoring the performance of HVAC units, fans, pumps, and other building systems, PLCs can detect early signs of potential malfunctions before they lead to system failure.

Real-Time Diagnostics: PLCs can continuously analyze the data from sensors and identify anomalies in system performance. For example, if an HVAC unit begins consuming more power than usual or fails to reach the set temperature, the PLC can trigger an alert to notify maintenance personnel [3, 5].

Reduced Downtime: Predictive maintenance ensures that equipment is serviced before it breaks down, reducing the need for costly repairs and minimizing downtime, which is especially critical during heatwaves or other extreme weather events.

The Future of PLC-Driven Climate Control in Building Design

As climate change continues to accelerate, the demand for flexible, automated climate control systems in buildings will only grow. PLCs will play an increasingly important role in designing resilient, sustainable, and energy-efficient buildings [2, 15]. Smart building systems, powered by PLCs, will help adapt to extreme weather, reduce energy consumption, and mitigate the effects of urban heat islands [16].

Integration with IoT and AI Technologies

The future of PLC-based climate control will see closer integration with Internet of Things (IoT) devices and artificial intelligence (AI). IoT devices will enable real-time communication between sensors and PLCs, while AI can optimize building operations based on predictive analytics, learning from past data to make future predictions about climate control needs [8].

Green Building Certification and Sustainability

As sustainability becomes a key concern in urban planning, the role of PLC-driven climate control systems in achieving green building certification (e.g., LEED, BREEAM) will increase. These systems will help building owners meet environmental regulations, improve energy efficiency, and reduce operating costs.

3. Conclusion

As urban centers continue to grow and face the impacts of climate change, the adoption of PLC-driven climate control systems offers a path forward for resilient and energy-efficient infrastructure. By leveraging real-time data processing, automation, and integration with renewable energy sources, these systems optimize building operations while minimizing environmental impact. Furthermore, advancements in IoT and AI technologies promise to further enhance the capabilities of PLCs, paving the way for smarter, more adaptive building systems. Ultimately, PLC-driven climate control systems are not only a response to current challenges but also a step towards sustainable urban development, ensuring that buildings remain comfortable, efficient, and environmentally responsible in the face of an uncertain climate future.

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