Частина II

СТУДЕНТСТВО. НАУКА. ІНОЗЕМНА МОВА

Збірник наукових праць

Міністерство освіти і науки України

ХАРКІВСЬКИЙ НАЦІОНАЛЬНИЙ АВТОМОБІЛЬНО-ДОРОЖНІЙ УНІВЕРСИТЕТ

СТУДЕНТСТВО. НАУКА. ІНОЗЕМНА МОВА

Збірник наукових праць

Випуск 17
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ТУРИЗМ, ГОТЕЛЬНО-РЕСТОРАННА СПРАВА
ПСИХОЛОГІЯ ТА ЗДОРОВ’Я
ПРИРОДНИЧІ НАУКИ

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У збірнику подано статті іноземними мовами з викладенням результатів наукових досліджень студентів, аспірантів та молодих науковців у різних галузях, що можуть зацікавити світову наукову спільноту. Регулярні публікації робіт допоможуть виявити талановиту студентську молодь, здатну брати участь у міжнародному професійному, науковому та освітньому обміні та втілювати одержаний досвід у розвиток передових технологій.

Усі матеріали публікуються в авторській редакції.

Зміст

ENGINEERING

Alieva T. V.

GOLD REFINING: TECHNOLOGICAL ASPECTS AND MODERN METHODS

Language Advisor – Senior Lecturer Tkachenko S.V

Gold is a chemical element with atomic number 79 and the symbol Au (from the Latin aurum). It belongs to the noble metals and has the following characteristic properties:

- Chemical resistance: gold does not oxidize in air and is resistant to most acids.
- Electrical conductivity: used in electronics due to its low electrical resistance.
- Decorative properties: its natural luster and yellow color make it popular in jewelry.
- Softness and ductility: it can be flattened to the thinnest sheets (gold foil) or stretched into wire with a thickness of only a few microns.

Gold has a symbolic meaning in different cultures, being a symbol of wealth, power and eternity.

Gold refining is one of the key processes in precious metals metallurgy, purifying gold from impurities to the level required for industrial or jewelry use. Various refining technologies are being developed to ensure high purity of the final product and minimize environmental impact. This article provides an overview of modern refining methods, technical schemes and environmental and economic aspects.

Gold mining starts with the primary source of gold, which is ore deposits that are processed by cyanidation. The bulk of gold comes in the form of alloys produced by melting zinc-treated gold precipitates, rough gold after amalgamation, placer gold obtained from the beneficiation of placers and ores, and cathode rough gold from thiourea regenerates. These materials have a complex chemical composition. In addition to gold and silver, they contain copper, lead, mercury, arsenic, antimony, tin, bismuth and other elements as impurities. The content of impurities can reach 200 samples or more. The main chemical reaction involves the dissolution of gold in a solution of sodium cyanide with oxygen to form complex compounds. The next stage is the extraction of gold from the liquid medium by adsorption on activated carbon or precipitation with zinc dust.

The main refining methods are:

1. Electrolytic method

Electrolytic refining, or the Wolvillian method, is the most efficient for achieving high gold purity (99.99%). This method uses an anode made of impure gold that dissolves in the electrolyte, leaving impurities as sludge. The method provides high quality but requires significant energy and equipment (Habashi, 1967).

2. Chemical method

The Miller process is based on the introduction of gaseous chlorine into molten gold. The resulting chlorides of impurities are removed, leaving gold of high purity. This method is cost-effective, but has limitations in terms of achieving purity above 99.5% (911 Metallurgist, n.d.).

3. Solvent extraction (Minataur™)

An innovative technology that involves the extraction of gold with solvents. This method allows to obtain gold with a purity of over 99.999%, having advantages in speed, efficiency and environmental friendliness. The purification process consists of several stages: leaching, extraction, precipitation and smelting (Van Deventer, 1997).

The refining process includes several key stages that differ depending on the method chosen.

For now, let's discuss the solvent extraction method, which in my opinion is the best of all. It includes the following steps:

- Preparation: grinding and enrichment of raw materials.
- Leaching.
- Impurity removal: Chemical or physical processes to purify a solution.
- Precipitation or extraction: The separation of gold from solution.
- Final processing: melting to produce bullion.

Solvent extraction is widely used in various industries for both upgrading and purifying a range of elements and chemicals. The technology is used in applications as diverse as ore processing, pharmaceuticals, agriculture, industrial chemistry, petrochemicals, food processing, base metal refining and precious metal refining. This review addresses the basics of solvent extraction techniques and discusses in detail its applications in several areas, focusing on ore processing and the extraction of important metals from an economic and industrial perspective. (5)

New refining technologies are focused on reducing environmental impact. For example, the use of biotechnology for gold leaching or the use of less toxic solutions reduces the amount of hazardous waste. In addition, closed cycles are being developed to reuse reagents (Marsden & House, 1992).

Modern gold refining methods ensure the production of high-purity metal that meets environmental and economic requirements. The choice of method depends on the characteristics of raw materials and production conditions. Innovations in this area help to improve process efficiency and reduce environmental impact.

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Bakaiev D. I.

THE FUTURE OF HYDRAULIC EXCAVATORS: INNOVATIONS, TRENDS AND PROSPECTS

Language Advisor – Asst. Prof. Chevychelova O. O.

Hydraulic excavators are indispensable in construction, mining, agriculture, and various other industries. Their versatility, power, and durability have secured a leading position among heavy machinery for decades. However, with advancements in technology and growing environmental concerns, the question arises: will hydraulic excavators adapt to meet modern requirements, or will they be replaced by alternative solutions? This article explores the current state of hydraulic excavators, their strengths and weaknesses, development prospects, and potential competitors.

Hydraulic excavators operate using pressurised hydraulic fluid to transfer power to actuators. This system ensures high precision, speed, and power, making these machines essential across numerous industries. They remain a top choice due to their reliability, flexibility, power, and versatility. Hydraulic systems enable excavators to generate the immense forces required for digging, handling stone, or dismantling structures. These machines also excel in harsh operating conditions, such as extreme temperatures, high humidity, and dust. With interchangeable attachments such as buckets, hydraulic hammers, and augers, they can perform a broad range of tasks.

Hydraulic excavators have retained their market dominance due to their indispensable nature in challenging environments. Their enduring popularity is tied to their adaptability, established infrastructure, and cost-effectiveness.

Transitioning to alternative technologies would necessitate significant investment in new service centres, staff training, and equipment upgrades.

According to market projections, the global hydraulic excavator market is expected to grow to $97.70 billion by 2032. For example, construction activity in the US increased from $1,626.4 billion in 2021 to $1,792.9 billion in 2022, driven by an annual growth rate of 10.2%. This construction boom continues to fuel demand for hydraulic excavators.

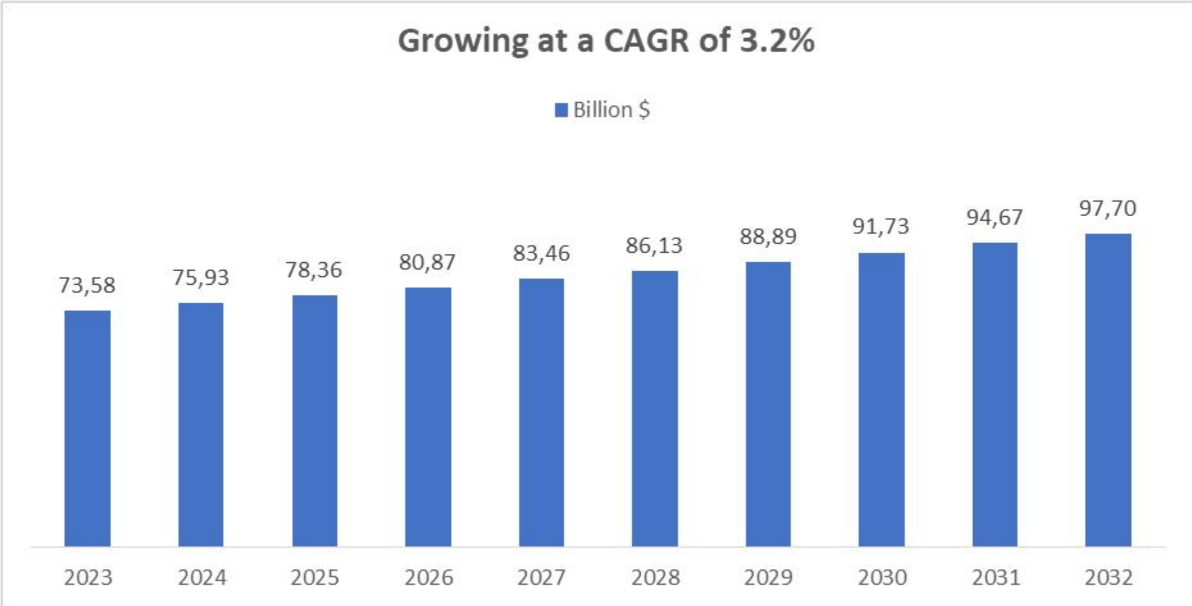

Figure 1 - The future of hydraulic excavators: statistics and prospects

Modernisation of hydraulic excavators is increasingly vital due to demands for energy efficiency, environmental sustainability, and digitalisation. Electric excavators, like Komatsu PC05E-1 introduced in 2023, reduce CO_2 emissions, eliminate fuel consumption, and minimise noise. However, their performance and autonomy are not yet on par with traditional hydraulic models, limiting their application to smaller projects. Machines powered by biodiesel, such as Komatsu PC205-10MO, provide environmentally friendly alternatives without sacrificing performance. Hybrid models, such as Komatsu HB365LC-3, combine hydraulic and electric systems to achieve up to 30% fuel savings while maintaining productivity. Advanced systems like Trimble Earthworks and Caterpillar Grade Control automate excavation processes, improving precision and cost-efficiency. The integration of AI and sensor technology enables real-time condition monitoring and predictive maintenance.

Despite emerging alternatives, hydraulic excavators retain their leadership due to their technological maturity, established infrastructure, and cost-effectiveness. Decades of optimisation have resulted in reliable systems offering exceptional performance at competitive costs. A robust global network of service centres ensures the availability of spare parts and skilled technicians. Electric and hydrogen-powered alternatives, while promising, remain more expensive to manufacture, purchase, and implement.

Hydraulic excavators are well-positioned to remain the cornerstone of heavy machinery for years to come. The future of the industry will hinge on the integration of advanced technologies, adherence to environmental standards, and the ability of manufacturers to adapt to evolving market needs. Innovations such as autonomous excavators, developed by companies like Built Robotics, and AI-driven automation will unlock new opportunities for efficiency and safety in hazardous environments. Additionally, advancements in engine technology, including electric and hydrogen-powered systems, will help minimise environmental impact. While hydraulic excavators face competition from emerging technologies, their balance of innovation and proven functionality ensures their continued relevance. By embracing digital transformation, sustainability, and resilience, the industry can meet the demands of a rapidly changing world.

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Bilous G.O.

GAS CYLINDER EQUIPMENT FOR CARS: ADVANTAGES, DISADVANTAGES AND CURRENT TRENDS

Language Advisor – Asst.prof. Vorobyova S.V.

Gas cylinder equipment is a modern way to reduce fuel costs for cars, which has become widespread due to its economy, environmental friendliness and long service life. The article highlights the main types of GCE, the principles of its operation, advantages and disadvantages, as well as the prospects for use. The main attention is on the advantages of gas fuel over traditional types, in particular gasoline and diesel. Modern GCE technologies and their impact on engine durability and reduction of harmful emissions into the atmosphere are considered.

Current trends in the automotive industry are focused on reducing the environmental impact of transportation.

The Principle of Operation of LPG Systems

LPG (Liquefied Petroleum Gas) systems offer a viable alternative to traditional gasoline or diesel fuel for internal combustion engines. The key to their operation lies in the properties of LPG itself and the components that facilitate its delivery to the engine.

Here is a breakthrough of the process:

1. Storage:

- LPG is stored in pressurized cylinders. The high pressure liquefies the gas, allowing for efficient storage in a compact form.

2. Vaporization:

- Before entering the engine, the liquid LPG must be converted back into a gaseous state. This vaporization process is typically handled by a vaporizer or reducer-evaporator.
- The vaporizer regulates the pressure and temperature of the LPG, ensuring a steady supply of gas to the engine.

3. Mixing with Air:

- The vaporized LPG is then mixed with air in a specific ratio to form a combustible mixture. This mixture is similar to the air-fuel mixture used in gasoline or diesel engines.

4. Combustion:

- The air-fuel mixture is ignited in the engine's combustion chamber, releasing energy that propels the vehicle.

Key Components of an LPG System:

1. LPG Tank: Stores the liquefied gas.

2. Vaporizer: Converts liquid LPG into gas.

3. Fuel Injection System: Delivers the gaseous LPG to the engine's intake manifold.

4. ECU (Engine Control Unit): Manages the overall operation of the LPG system, including fuel injection timing and mixture ratio.

5. Switching System: Allows the vehicle to switch between LPG and gasoline fuel.

Advantages of LPG:

1. Lower Fuel Costs: LPG is generally more affordable than gasoline or diesel.

2. Reduced Emissions: LPG produces fewer harmful emissions, including lower levels of carbon monoxide and particulate matter.

3. Increased Engine Life: LPG is a cleaner fuel, which can contribute to longer engine life.

By understanding the fundamental principles of LPG systems, it's clear how this alternative fuel can provide a cost-effective and environmentally friendly solution for powering vehicles.[2].

Modern LPG systems consist of the following elements:

1. Gas storage cylinder (methane or propane)

2. Reducer-evaporator

3. Gas nozzles

4. Electronic control unit (ECU), which adapts the gas supply according to engine operation.

Advantages of using LPG

1. Cost savings. Gas is cheaper than gasoline or diesel.

2. Environmental friendliness. Gas fuel has lower emissions of carbon dioxide (CO_2), nitrogen oxides (NOx)

3. Engine durability. Less soot in the combustion chamber, additional piston service life

4. Availability. Gas filling stations are becoming more common. [1]. Disadvantages of LPG

1. Additional installation costs. Equipment and its installation require significant initial investments

2. Reduction in trunk volume. The cylinder takes up all the space.

3. Engine power losses. Gas has a lower energy content than gasoline.

4. Ability to service LPG. Gearboxes and nozzles are required regular technical inspection.

Types of LPG

1. Modern LPG systems are divided into generations depending on the level of technological sophistication. The most widespread today are the fourth and the fifth generations, which provide a high level of gas injection accuracy and stable engine operation. [3].

Current trends

Gas cylinder equipment is a rational choice for those who seek to reduce the operating costs of a car. Gas cylinder equipment (LPG) is a modern solution that allows you to significantly reduce fuel operating costs, increase the environmental friendliness of cars and ensure the durability of the engine. The use of gas fuel, such as methane or propane-butane, is not only economically beneficial, but also helps reduce harmful emissions, which is important in the context of modern environmental challenges.

However, the transition to LPG requires abandoning planning, taking into account both advantages and disadvantages, initial installation costs, reduced trunk volume and the need for regular maintenance.

Modern technologies, such as the fourth and fifth generation of LPG, provide high efficiency, fuel delivery accuracy and engine stability, making this type of equipment increasingly attractive to car owners. In addition, the development of gas filling station infrastructure worsens the popularity of LPG.

In general, the use of gas cylinder equipment is a rational choice for those who seek to reduce fuel costs, reduce the environmental impact of transport and ensure the reliability of the car in the long term. The prospects for the development of LPG are also associated with the integration of innovative technologies.

This confirms that LPG is the first step towards environmental and economic sustainability.

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Burakov I. A.

METHODS OF VIBRATION REDUCTION IN VEHICLES

Language Advisor – DSc (Education), Prof. Saienko N.V.

Vibrations in vehicles pose significant challenges to comfort, safety, and structural integrity. This paper explores the causes of these vibrations and presents common and innovative methods for reducing their impact. Techniques such as passive damping systems, active vibration control, and strategic design choices offer solutions to enhance vehicle performance and user experience.

Vibrations in vehicles are a common phenomenon resulting from various sources such as road irregularities, engine operation, and aerodynamic forces. These vibrations not only affect passenger comfort but also have a substantial impact on the vehicle's longevity and safety. The study of vibration reduction methods is essential to improve driving comfort, reduce noise, and increase the durability of vehicle components.

Causes of Vibration in Vehicles

The primary sources of vibrations in vehicles include:

- Engine Vibrations: Engines, especially those with internal combustion, generate considerable vibrations due to the cyclic nature of combustion processes.
- Road Irregularities: Uneven road surfaces produce vibrations that are transmitted to the vehicle's body, creating a rough driving experience.
- Aerodynamic Factors: At high speeds, air resistance and turbulence can cause vibrations, impacting the stability and comfort of the vehicle.

Understanding these causes is the first step in effectively addressing and mitigating the vibrations experienced in vehicles.

Methods for Vibration Reduction

1. Passive Damping Systems

Passive damping systems are widely used in vehicles to absorb and dissipate vibrational energy. Their key components include:

- Shock Absorbers and Springs: Shock absorbers, often in combination with springs, absorb kinetic energy from road irregularities and reduce its transmission to the vehicle's frame.
- Elastic Materials: Rubber and polyurethane are used in various parts of the vehicle, including mounts and bushings, to dampen vibrations.

2. Active Vibration Control Systems

In recent years, active vibration control systems have gained attention due to their ability to dynamically adjust to changing conditions:

- Electromagnetic Dampers: These systems use electromagnetic forces to counteract vibrations in real-time, providing greater control over the vehicle’s stability.
- Hydraulic Systems: Advanced hydraulic dampers can adapt their stiffness to absorb vibrations more effectively, particularly in luxury and high-performance vehicles.

3. Design and Structural Adjustments

Design strategies play a crucial role in reducing vibration:

- Balancing: Properly balanced wheels, shafts, and other rotating parts help minimize vibration by reducing uneven mass distribution.
- Structural Reinforcements: Stiffening the vehicle’s frame and chassis can prevent excessive vibrations from spreading across the vehicle’s body.

Impact on Comfort and Safety

Reducing vibrations enhances comfort by providing a smoother ride and reducing noise levels inside the cabin. For drivers, lower vibrations mean less fatigue during long drives, contributing to improved concentration and overall road safety. Additionally, decreased vibrations can prevent wear and tear on mechanical parts, extending the lifespan of various vehicle components.

The Importance of Innovations in Vibration Reduction in the Modern Automotive Industry

The modern automotive industry is highly focused on enhancing passenger comfort and safety, making vibration reduction methods an essential aspect of engineering design. With continuous technological advancements, automotive companies are now capable of implementing state-of-the-art solutions that significantly improve ride comfort and safety by reducing vibration and noise levels within the vehicle cabin. Innovations such as active vibration control systems, which employ electromagnetic dampers or adaptive hydraulic systems, allow vehicles to quickly respond to changing road conditions, thus ensuring stability at high speeds.

In addition to increasing passenger comfort, reducing vibration levels contributes to the longevity of vehicle components, lowering maintenance and repair costs. This also has a positive environmental impact, as the extended lifespan of vehicles reduces the need for frequent part replacements, thereby diminishing the environmental footprint.

Future Technologies and Trends

With advancements in technology, more sophisticated solutions for vibration reduction are emerging:

- Adaptive Materials: Research is underway on materials that change properties in response to vibrations, offering adaptable solutions for enhanced damping.
- Smart Control Systems: Integrating artificial intelligence with vibration control systems allows for proactive adjustments to driving conditions, further improving the ride quality.

Addressing vibrations in vehicles is crucial for achieving optimal comfort, safety, and durability. Through a combination of passive and active damping, along with thoughtful design, manufacturers can significantly enhance the driving experience. As technology evolves, future solutions will likely become even more efficient, setting new standards in vibration reduction and vehicle stability.

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Drobiazko V.A.

PROSPECTS FOR THE DEVELOPMENT OF PISTON INTERNALCOMBUSTION ENGINES

Language Advisor – Senior Lecturer Ivanova I.L.

Today, more than 70% of the world's energy is produced by piston internal combustion engines (ICE). In addition, piston engines remain, for the foreseeable future, the most economical units in the range from 5 kW to 100 MW for a single installation. They are almost irreplaceable in such vital sectors of the economy as transportation, mining, agricultural and road construction machinery, and small autonomous energy systems. The technical level of piston ICEs and systems based on them, in terms of fuel efficiency, reliability, emission cleanliness, weight and size characteristics, automation, and other parameters, largely determines the level of excellence and competitiveness of operating assets (ships, locomotives, cars, power plants, etc.) as well as the rational use of key operational materials (oil, fuel, metals), and the costs of servicing and repairing these assets. The development of engine manufacturing directly impacts the growth of a number of industries that use

ICEs and support engine manufacturing (such as metallurgy, machine tool building, petrochemicals, electrical engineering, and electronics). The presence of a domestic scientific and industrial base is one of the most important factors in the development of engine manufacturing in a country. Piston engines are among the most research-intensive and labor-intensive types of engineering products. For example, creating a new engine size, even for advanced foreign firms with no financial constraints, takes 3-5 years and costs hundreds of millions of dollars. Since piston engine manufacturing has been determined by necessity to remain the foundation of global energy in the near future, it is advisable to consider the conceptual issues of the scientific and technical development of piston engines and the priorities for their improvement.

The transportation sector, as is well known, holds great national significance for the economy, and the pace of development in the transportation piston engine industry is crucial. As is also known, gasoline engines and diesel engines are used in cars, with the share of diesel engines steadily increasing. The development of gasoline and diesel automotive engines is focused on improving fuel efficiency and meeting future environmental standards. Today, EURO-4 environmental standards are already being implemented, though achieving the less stringent EURO-3 standards is still a challenging task. Generally, compliance with EURO-3 standards is achieved through the use of exhaust gas neutralizers and the introduction of microprocessor control.

All known concepts for gasoline and diesel engines that can meet EURO-4 standards involve fundamental changes to engine design and significant development of control systems. EURO-4 standards cannot be met without the creation of engines with flexible, multi-parameter control of operating processes and the use of adaptive self-tuning and self-learning systems. Moreover, the creation of competitive models requires the development of electronic information and control systems that integrate vehicle and engine management.

Microprocessor control of intelligent internal combustion engines (ICE) has already been practically implemented, improving their environmental and economic characteristics through a high level of individual optimization of the working process in each cycle of each cylinder. This is achieved by automatically selecting and setting a combination of values for the working process parameters in the engine cylinders and control algorithms that are optimal for fuel consumption and the quality of transitional processes, while adhering to environmental and technical constraints.

A key condition for the effective implementation of microprocessor control in ICE is the presence of electronic fuel injection and gas exchange systems. The most efficient fuel systems currently produced in series are accumulator systems with electronically controlled injectors (ECIs). ECIs include electromagnetic control valves and a hydraulic booster drive for injector needles. All fuel injection control functions in accumulator systems are implemented by an onboard microcontroller. These systems have the broadest range of independent, pulse-based control over fuel injection parameters (duration, phase, pressure, and injection profile shape), essential for optimizing working processes.

It is the accumulator electronic fuel systems that enable automotive diesel engines to meet environmental standards, not only for EURO-3 but also for subsequent, more stringent requirements. Microprocessor control of air charge parameters creates additional opportunities for optimizing diesel engine working cycles. Electronic control of the geometry of intake and exhaust channels and the recirculation of exhaust gases provides additional improvements to the working cycles of internal combustion engines. The active application of systems using electromagnetic valves has already begun, for example, in passenger car and truck engines. High-speed electromagnetic valves allow individual optimization of the duration, phase, and movement of each valve (both intake and exhaust) at any time and under any engine operating condition, even to the point of completely shutting off cylinders.

Another crucial factor that determines the effectiveness of microprocessor control in engines is the control algorithms, particularly for regulating rotational speed, which are implemented by microcontrollers. The application of rational algorithms in combination with pulse control of fuel and air supply ensures the achievement of the best possible performance indicators. This primarily pertains to the accuracy of maintaining rotational speed in steady states, the magnitude of maximum deviation, and the duration of transitional processes during starting, acceleration, loading, and load change. Nonlinear algorithms implemented in microcontrollers are considered the most effective for regulating the rotational speed of engines, especially diesel generators. It has been established that optimizing the rotational speed control system for response time minimizes both the maximum and minimum deviations of rotational speed during transitional processes.

Consequently, fuel consumption and harmful emissions are reduced. Improving the quality of rotational speed regulation by microprocessor controllers in steady states also allows for a decrease in the minimum stable idle speed. Thus, the comprehensive control algorithms for intelligent engines generally include optimal adaptive control algorithms for timing, pressure, number of phases, fuel injection profile shape, fuel supply limits, fuel cutoff when ignition and effective combustion conditions are not met, phases of gas distribution, boost pressure, and more. Additionally, the use of non-intrusive automatic technical diagnostics is essential. In all diesel engines with electronic control devices, there has been a significant reduction in operational fuel consumption, exhaust gas temperatures, and harmful emissions. Start-up and braking characteristics have also improved, as well as durability and reliability.

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Golovan A. I.

INNOVATIVE MATERIALS IN MECHANICAL ENGINEERING

Language Advisor – Asst. Prof. Vorobyova S. V

The development and application of innovative materials are critical for advancing mechanical engineering. Such materials enhance the performance, durability, and efficiency of mechanical systems while contributing to environmental sustainability. This paper explores key trends and examples of innovative materials used in modern mechanical engineering, focusing on their properties and applications.

1. High-Performance Alloys

High-performance alloys, such as titanium and nickel-based superalloys, are widely used in industries like aerospace and automotive. These materials offer exceptional strength-to-weight ratios, corrosion resistance, and the ability to maintain mechanical properties under extreme temperatures.

- Titanium Alloys: Frequently employed in aerospace applications, titanium alloys are lightweight, corrosion-resistant, and exhibit high fatigue strength. For example, the use of titanium in aircraft components reduces overall weight, thereby improving fuel efficiency.

- Nickel-Based Superalloys: Commonly used in turbine blades, these materials exhibit excellent creep resistance and thermal stability. Their ability to function reliably in high-temperature environments makes them indispensable in gas turbines and jet engines.

2. Composite Materials

Composite materials combine two or more constituents to produce a material with enhanced properties. Carbon fiber-reinforced polymers (CFRPs) and glass fiber-reinforced polymers (GFRPs) are prime examples.

- Carbon Fiber Composites: Known for their high strength and low weight, carbon fiber composites are extensively used in sports equipment, automotive components, and aircraft structures. For instance, carbon fiber is integral to the construction of Boeing's 787 Dreamliner, which boasts a lighter frame and improved fuel efficiency.

- Glass Fiber Composites: These materials are more cost-effective than carbon fiber composites and are used in applications like wind turbine blades and structural components in buildings.

3. Smart Materials

Smart materials adapt to environmental changes, making them ideal for advanced engineering applications. Examples include shape memory alloys (SMAs), piezoelectric materials, and self-healing polymers.

- Shape Memory Alloys: SMAs, such as Nitinol, can recover their original shape after deformation when exposed to specific temperatures. They are used in actuators, sensors, and medical devices like stents.

- Self-Healing Polymers: These materials autonomously repair cracks and damages, extending the life span of components. They are applied in coatings, structural materials, and electronics.

4. Ceramics and Advanced Coatings

Ceramics and advanced coatings play a significant role in enhancing wear resistance, thermal stability, and corrosion protection in mechanical systems.

- Ceramic Matrix Composites (CMCs): These are used in high-temperature applications, such as jet engines and power turbines, due to their excellent thermal resistance and strength.

- Advanced Coatings: Techniques like thermal barrier coatings (TBCs) protect components from high temperatures and oxidation. For example, TBCs are crucial in extending the life of turbine blades.

5. Nanomaterials

Nanotechnology enables the manipulation of materials at the atomic level, leading to significant improvements in strength, conductivity, and thermal properties.

- Nanotubes and Graphene: Carbon nanotubes and graphene have remarkable mechanical and electrical properties. They are used in applications ranging from lightweight structural components to high-performance batteries.

- Nanocoatings: These coatings provide superior wear resistance, hydrophobicity, and antibacterial properties. For instance, nanocoatings on cutting tools enhance their durability and performance.

Conclusion

The adoption of innovative materials in mechanical engineering drives advancements in technology and sustainability. High-performance alloys, composite materials, smart materials, ceramics, and nanomaterials are transforming industries by improving efficiency and reliability. As research continues, the development of even more advanced materials will further revolutionize the field, addressing challenges related to performance, cost, and environmental impact.

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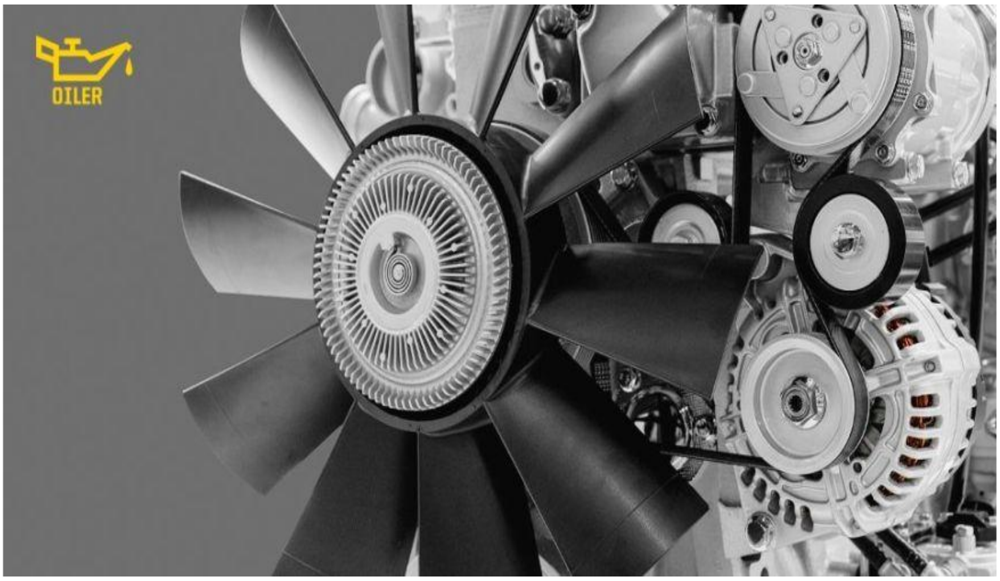
Goltsev O.A.

INTERNAL COMBUSTION ENGINE IN A PASSENGER CAR

Language Advisor – Asst. Prof.Vorobyova S. V.



I. What is an internal combustion engine in a car and how does it work?

An internal combustion engine or internal combustion engine is one of the main units in any modern car. Thanks to this unit, the car gets the opportunity to move in space: the engine converts the piston movements into the rotation of the crankshaft. Note that the power unit is installed not only in cars, but also in motorcycles, ships, locomotives, airplanes and many other types of vehicles. In addition, various tools and certain types of equipment are equipped with the engine.

II. Who invented the first internal combustion engine and when?

John Barber - invented the gas turbine in 1791.

Etienne Lenoir - invented the gas "Lenoir engine" in 1860. It was the first ICE to be mass-produced.

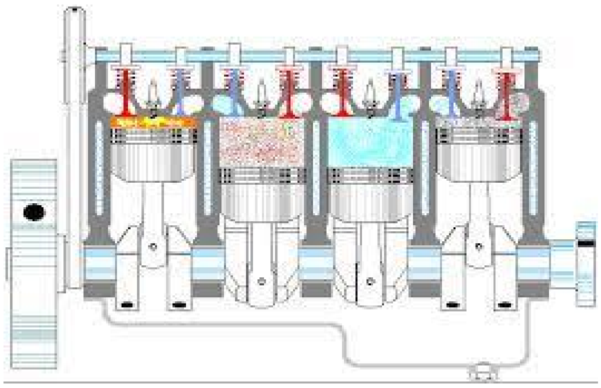
Nikolaus Otto - developed a spark-ignition engine in 1861.

George Brighton - patented a two-stroke, two-cylinder ICE in 1872.

It is impossible to say for sure who invented the ICE, since many inventors participated in the design and development of this mechanism.

It is believed that the first to invent the ICE is Etienne Lenoir. He designed an engine with a capacity of only 12 hp.

III. The device of the internal combustion engine



Note that the structure of the internal combustion engine may differ, since there are many types of power units. The most famous today is the piston type. It is such mechanisms that are installed in most cars. In addition, there are other types of internal combustion engines - these are less common gas turbine and rotary-piston.

For example, consider the structure of a piston engine. Its main part is the housing. It includes a cylinder block and a head, as well as two mechanisms:

Crank-connecting rod and gas distribution, which admits clean air and releases exhaust gases.

IV. How an internal combustion engine works

The principle of operation of an internal combustion engine is based on the effect of thermal expansion:

Fuel burns inside the engine.

Thermal expansion occurs, which affects the piston of the unit.

This component is set in motion, due to which the crankshaft begins to rotate. This ensures the operation of the entire assembly.

In one cycle, the crankshaft rotates twice, and the process itself includes several strokes. To understand how an internal combustion engine works.

V. Types of internal combustion engines

Piston - the most common mechanisms. We have described the principle of their operation above.

Carburetor - before being fed into the cylinders, the combustible mixture is formed directly in the carburetor.

Injection - fuel is injected into the manifold through nozzles.

Diesel - unlike gasoline internal combustion engines, the mixture is ignited by high temperature. That is, spark plugs are not used in such units.

Rotary - energy is transformed by the rotation of the rotor by gases.

Gas turbine - a gas turbine drives a supercharger. This unit compresses the air immediately before igniting the mixture.

VI. The structure of the internal combustion engine: the advantages of the unit

If we do not consider the design features of each power unit separately, all mechanisms are characterized by a number of advantages. It is they who determine the wide application of these units:

- autonomy;

- relatively low cost;
- multi-fuel - there are mechanisms that run on gasoline, diesel and gas;
- high degree of reliability of the unit;
- unpretentiousness in operation;
- relative ease of maintenance.

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Kalashnyk M. O.

OPTIMISING VEHICLE MAINTENANCE FOR A SUSTAINABLE FUTURE

Language Advisor – Asst. Prof. Chevychelova O. O.

Vehicles are essential to modern society, enabling the efficient transportation of people and goods. They encompass a variety of types, including cars, trucks, buses, motorcycles, and forms of water, air, and rail transport. To ensure these vehicles function effectively and safely, regular maintenance and repair are crucial.

Vehicles are classified based on their transport type, purpose, design, and usage. Among the most common are passenger cars, freight trucks, buses, and specialised vehicles such as agricultural and construction machinery.

Passenger cars dominate urban and suburban landscapes, designed for personal use and typically compact for manoeuvrability. Their models cater to diverse needs, ranging from economy vehicles to luxury options. Trucks, in contrast, are larger and more powerful, built to transport goods and equipped for specialised cargo types, including hazardous or perishable materials. Specialised vehicles, like snowploughs or excavators, are engineered for specific tasks in fields like agriculture, construction, or logistics.

Each vehicle operates through interconnected systems that ensure functionality. The engine, often termed the vehicle's heart, directly impacts performance, fuel efficiency, and emissions. Advances such as turbocharging, alternative fuels, and injection systems have enhanced engine sustainability. The transmission transmits power from the engine to the wheels, with manual and automatic options supporting efficiency and driving comfort.

Safety hinges on systems like the brakes, which may employ disc, drum, hydraulic, or pneumatic mechanisms. The suspension absorbs shocks from uneven roads, improving stability and comfort. Modern vehicles also integrate sophisticated electrical and electronic systems that enhance safety, such as ABS and ESP, and provide amenities like climate control and multimedia.

Another crucial element of vehicle maintenance is tyre care. Tyres play a significant role in safety, fuel efficiency, and driving performance. Ensuring proper inflation levels, maintaining tread depth, and rotating tyres at regular intervals are essential practices that prolong tyre life and improve road grip. Neglecting tyre maintenance can lead to increased risks of blowouts, reduced fuel economy, and compromised handling.

Fuel system maintenance is also vital to optimising engine performance and reducing emissions. Over time, fuel injectors can become clogged, and filters may degrade, leading to reduced efficiency and potential engine damage. Regularly checking and replacing fuel filters, along with using quality fuel, helps prevent these issues and ensures smooth vehicle operation.

The importance of climate-specific maintenance cannot be overstated. In colder climates, vehicles require specialised preparation, such as winter tyres, anti-freeze fluids, and battery care, to prevent breakdowns caused by extreme temperatures. Similarly, in regions with high temperatures, cooling systems and air conditioning units need regular inspection to ensure proper functioning and prevent overheating.

Moreover, the environmental impact of vehicle maintenance is increasingly under scrutiny. Proper disposal of used oils, tyres, and other waste materials is crucial to minimising ecological harm. Recycling components where possible and adopting eco-friendly maintenance practices, such as using biodegradable lubricants and fluids, contribute to sustainability while maintaining vehicle performance.

Regular vehicle maintenance is critical for safety, reliability, and longevity. Scheduled inspections typically occur every 10,000 to 20,000 kilometres or six to twelve months, depending on the vehicle type and operating conditions. Diagnostics, leveraging electronic systems, facilitate the detection and resolution of even minor defects, reducing the risk of major failures. Repair and replacement, when required, benefit from using certified spare parts, ensuring compatibility and reliability.

Innovations have significantly influenced vehicle maintenance. The rise of autonomous vehicles has introduced unique challenges, as their complex electronic systems require specialised servicing. Electric vehicles demand new maintenance approaches focused on battery care and electrical systems. The Internet of Things (IoT) enables real-time vehicle monitoring, predicting maintenance needs and pre-empting failures.

In conclusion, vehicle maintenance is integral to their safe, efficient, and reliable operation. Regular servicing not only extends the life of a vehicle but also ensures safety, environmental sustainability, and comfort for users. As technologies evolve, the nature of maintenance is becoming increasingly sophisticated, reflecting the integration of digital systems, alternative energy sources, and autonomous functionalities.

Moreover, the role of predictive technologies like IoT and data analytics is transforming traditional maintenance practices, enabling real-time monitoring and proactive interventions that minimise downtime and enhance operational efficiency. These advancements signify a broader move towards eco-conscious and technologically driven maintenance strategies, aligning with global sustainability goals.

The future of vehicle maintenance is set to be defined by continuous innovation, adaptability, and a focus on training professionals to manage these advanced systems effectively. By embracing these developments, the transport industry will not only meet the demands of modern society but also contribute to creating a safer, greener, and more efficient mobility ecosystem.

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Khasanov V. V.

THEORETICAL DETERMINATION OF THE INFLUENCE OF THE KINEMATIC PARAMETERS OF THE EARTHMOVER'S WORKING EQUIPMENT ON THE EFFICIENCY OF DEEP VIBRATION CUTTING OF COHESIVE SOILS

Scientific Advisor – Asst. Prof., Cand. Tech. Sci. Ragulin V. M.
Language Advisor – Cand. Ped. Sc., Assoc. Prof. Skrypnyk N. S.

With the rapid development of technology and the economy, people's concern for environmental protection is growing and their desire for quality of life is increasing. A sustainable development regime that combines urban construction and environmental protection has gradually become a major trend in our time. In the course of urban development, there is a growing need to develop underground infrastructure, lay pipelines for gas distribution networks, power cables of various types, drainage systems, water supply and sewage networks, etc. Traditional excavation methods not only cause damage to the environment and urban infrastructure, but also waste time and labour. Horizontal Directional Drilling (HDD) is a non-invasive alternative to trenching that is used to install many conventional utilities and offers significant advantages over traditional methods of laying utilities. The use of HDD minimises environmental impact.

According to research, this technology reduces the amount of land work and the risk of soil erosion, which ensures the preservation of ecosystems even in sensitive areas, such as urban areas or nature conservation areas (Lubrecht, 2012, pp. 2484-2489; Hua, 2022, p. 12207).

For example, studies show that HDD reduces the time spent on laying utilities by 30-50% due to the optimisation of the drilling process and the absence of the need for largescale landscape restoration. In addition, the use of HDD helps to reduce the impact on water resources and minimise the risk of water pollution, making this method more environmentally friendly than traditional trenching technologies (Lubrecht, 2012, p. 2484- 2489).

The practical application of HDD has already proven its effectiveness in large-scale infrastructure projects, such as laying pipelines under rivers, roads and other difficult conditions. For example, China has successfully implemented HDD for projects up to 5 km long, which confirms the high efficiency and technical adaptability of this technology (Hua, 2022, p. 12207).

This work is carried out by special earthmoving machines based on the formation of a deep slot in the soil with knife-like working tools. This process requires significant traction. It is known that various methods of intensification are used to reduce it: vibration, lubrication, transportation, coating with antifriction materials, etc. (Zhu, 2016, p. 915-921; Hua Tong, 2022; Lan, H, 2011, p. 415-421; Lubinski, 1962, p. 655-670).

One of the most effective methods is mechanical oscillation of the working equipment due to its kinematics.

Therefore, the issue of determining the impact of deep tillage on the intensification process is important both from a scientific and practical point of view.

The technology of trenchless underground utilities has been widely implemented in production and is well covered in many studies by domestic and foreign authors.

The issues of laying pipelines and other types of engineering communications in various conditions, including mountainous and wetlands, by open-cutting and without trenching are presented in works (Zhu, 2016, p. 915-921; Hua Tong, 2022; Lan, H, 2011, p. 415-421; Lubinski, 1962, p. 655-670; Tkachuk M.M., 2013. P.391; Rudnev V.K., 2015, p. 100-107). They consider the technologies of work performance, principles of selection of machinery and mechanisms for earthworks.

The improvement of the process of creating trenches for linear objects is presented in studies (Kravets S., 2020, p. 23-28; Jin, L., 2022), which showed the possibility of increasing the productivity of creating trenches for laying utility lines by using less energy-intensive technologies of soil development with the working equipment of continuous action chain multi-scraper excavators.

The aim of the study is to develop scientifically based recommendations for reducing the resistance of deep soil cutting by a knife tillage tool due to its vibration-oscillatory movements.

If you designate the oscillation frequency - ω, the amplitude – S, then at fixed values of the speed of the working body in the horizontal plane – you can record the value of the path and speed of movement of the cutting edge at any time t:

$$x = \vartheta t \mp S \cdot \sin \omega t \qquad (1)$$

$$x = \vartheta \mp S\omega \cdot \cos \omega t \qquad (2)$$

For a given direction of oscillation, depending on the ratio of translational ϑ and vibration $S\omega$ speeds, there are two typical cases of interaction between the working implement and the soil.

One: $\frac{\vartheta}{S\omega} > 1$, then x will always be positive, and the displacement value at any given time will have an increasing gradient. In other words, the cutting process will resemble "pushing" a stamp with a variable force over a period of time. A graphical representation of the first case is shown in Figure 1.

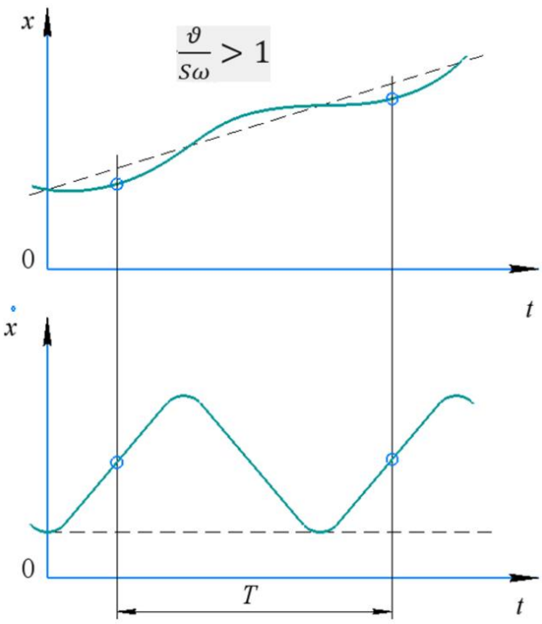

Figure 1. View of the graph of the knife path and speed under the condition: $\frac{\upsilon}{S\omega} > 1$

It should be noted that the maximum force at the moment of impact is achieved at the highest blade speed at the moment of “reaching” the soil, which should correspond to a single value of the machine speed at a fixed vibration.

For an analytical study of the latter conclusion, we will use the known performance indicators for cutting force:

$$\delta^p = \frac{P_{cm} - P_{ві6}}{P_{cm}}, \qquad (3)$$

where P_{cm} and $P_{Ві6}$ – are respectively the cutting forces with a non-vibrating and vibrating knife.

The energy consumption during vibratory cutting can be estimated using a similar indicator:

$$\delta^N = \frac{N_{ві6} + N_M}{N_{cm}}, \qquad (4)$$

where $N_{cm} = P_{cm} \ \upsilon$ – is the tractor power for traditional static soil cutting; $N_{ві6} = P_{ві6} \ \upsilon$ – is the tractor power for vibratory soil cutting; $N_м$ – is the power of the vibrator drive (vibratory machine).

Substituting the expressions into the general formula, we get the following:

$$\delta^N = \frac{P_{cm} \cdot \vartheta - (P_{ві6} \cdot \vartheta + N_M)}{P_{cm} \cdot \vartheta} = \frac{P_{cm} - P_{ві6}}{P_{cm}} - \frac{N_M}{P_{cm} \cdot \vartheta} = \delta^p - \frac{N_M}{P_{cm} \cdot \vartheta} \quad (5)$$

If the expression $\frac{N_M}{P_{cm} \cdot \vartheta}$ is denoted as δ^B, then dependence (5) will take a complete form:

$$\delta^N = \delta^p - \delta^B \qquad (6)$$

On the basis of the established value of the path and speed of movement of the knife working body at any moment of time from the frequency of its oscillation, amplitude at fixed values of the speed of movement, the direction of oscillations is determined depending on the ratio of translational and vibration speeds, for which two typical cases were considered.

Further research will allow developing mathematical models that take into account the dynamic change in the physical and mechanical properties of soils under the influence of vibration and oscillatory movements of the knife working body.

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Krainiuk M. Yu.

INTEGRATION OF AI AND IOT INTO THE MANAGEMENT OF MACHINE AND TRACTOR UNITS

Scientific Advisor – Cand. Tech. Sc., Assoc. Prof. Shcherbak O.V.
Language Advisor – Cand. Ped. Sc., Assoc. Prof. Skrypnyk N. S.

Integrating artificial intelligence (AI) and the Internet of Things (IoT) into machine and tractor units for urban and construction work is changing how we manage and operate machinery. Traditionally, operators have operated machines manually, using their own experience and physical strength to complete tasks. However, introducing AI allows for the automation of a significant part of these processes.

AI analyses large amounts of data in real-time, optimising machine performance, ensuring task accuracy, and reducing human error. AI systems can make decisions independently, such as route processing, trajectory correction, engine load adjustment, and other key parameters. At the same time, IoT allows machines, sensors, and analytical systems to be connected to a single network, creating an integrated ecosystem for continuous monitoring and control.

Let's analyse the main opportunities offered by the integration of AI and IoT in the management of modern machine and tractor units. The diagram (Fig. 1) shows aspects such as automatic control, which reduces the need for constant operator presence, breakdown prediction through sensor data analysis, and real-time monitoring of system status to maintain high productivity and respond quickly to malfunctions. These technologies increase machine efficiency and minimise the risk of downtime.

The introduction of autonomous systems based on AI and IoT is fundamentally changing the approach to managing construction and urban machines, allowing for the automation of complex processes and increased accuracy of tasks. Major global companies are actively integrating these technologies into their machinery, ensuring more efficient and safer operations.

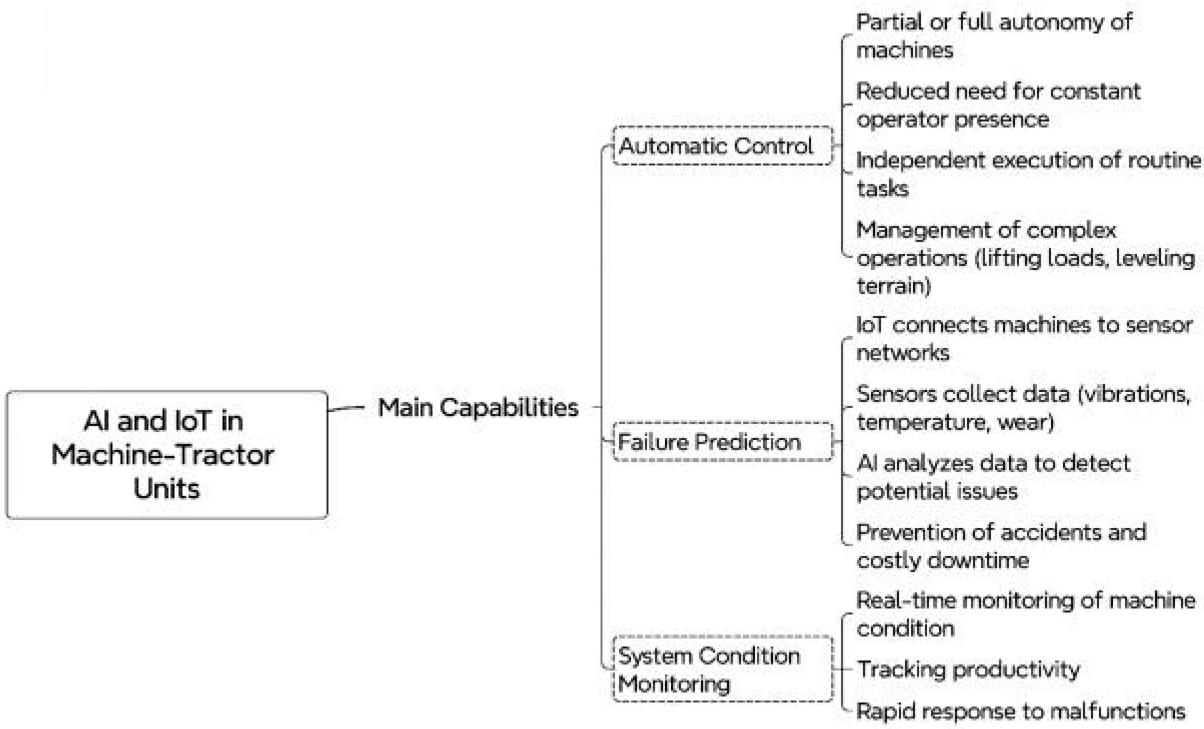

Figure 1. Integration of AI and IoT into the management of machine and tractor units: main opportunities

Autonomous AI and IoT systems are already being actively implemented in the construction industry. Modern excavators and bulldozers are equipped with systems that automatically adjust the bucket lifting height, handle terrain with centimetre accuracy, and can perform complex manoeuvres without operator intervention. This reduces errors and speeds up the completion of tasks.

For example, Caterpillar has introduced Cat® Command [1], which allows excavators and bulldozers to work remotely or autonomously. This system automatically adjusts the bucket lift height and ensures terrain accuracy of up to several centimetres. Komatsu has developed the Smart Construction system, which uses AI and IoT to automate construction processes, including independent earthworks using sensors to precisely level the ground [2].

Volvo Construction Equipment is actively integrating autonomous systems into its machines, including excavators that can perform various operations, including loading and unloading materials, on their own.

For example, their LX03 autonomous wheeled loader concept is self-learning and capable of making decisions and performing tasks without human intervention. This prototype uses artificial intelligence to collaborate with humans to perform hazardous or routine tasks on construction sites, reducing risks to workers and increasing the efficiency of operations. The LX03 is also a zero-emission electric machine, which underlines Volvo's commitment to sustainability [3].

Another example is the TA15 autonomous dump truck, which is powered by electric traction and designed to perform repetitive tasks such as transporting goods on construction sites. The TA15 can operate around the clock without human intervention, which significantly increases productivity and reduces the impact of human error on safety [4].

These examples demonstrate how major engineering companies are using AI and IoT to create intelligent, autonomous solutions that increase efficiency and safety on construction sites.

Other examples of AI and the Internet of Things (IoT) being used in autonomous road construction machines include Volvo Construction Equipment, which is introducing autonomous road rollers and other machines. The Volvo CX01, for example, is an autonomous asphalt roller powered by electricity. This machine uses sensors and artificial intelligence algorithms to accurately measure and correct the compaction of the pavement, which reduces the need for human intervention and improves the quality and safety of work.

In cities, autonomous snow ploughs and road rollers significantly increase the efficiency of infrastructure maintenance. For example, in Ottawa and Kingston (Canada), IoT systems are being implemented to track the location of snowplows in real time [5]. This allows for more efficient route planning, taking into account weather conditions and pavement conditions, which helps to avoid skipping certain sections of streets and reduces cleaning time. Data on equipment performance is collected and analysed to optimise future performance, and is also made available to residents through apps to better plan their trips during snowfalls.

Thanks to AI integration, such machines can optimise routes for street cleaning or road repair, taking into account road surface conditions, weather conditions and other variables. IoT systems allow city services to remotely monitor their location and performance. Other examples include the introduction of AI algorithms to predict road surface conditions and automatically make decisions on the use of salt or other materials to combat snow and ice, which significantly increases the efficiency of winter street maintenance. These systems help reduce the workload on staff and improve road safety, especially during heavy snowfall.

Integration of AI into machine and tractor units allows automating the process of route optimisation, which leads to a significant increase in efficiency (Fig. 2). For example, by analysing data from sensors such as GPS and other monitoring systems, machinery can independently determine the most efficient routes for performing tasks, taking into account current road conditions, traffic jams, and even weather conditions. This helps to reduce downtime and fuel costs, as optimised routes reduce the overall distance travelled. Studies show that this use of AI can reduce maintenance costs and increase productivity by 20-30% compared to traditional methods.

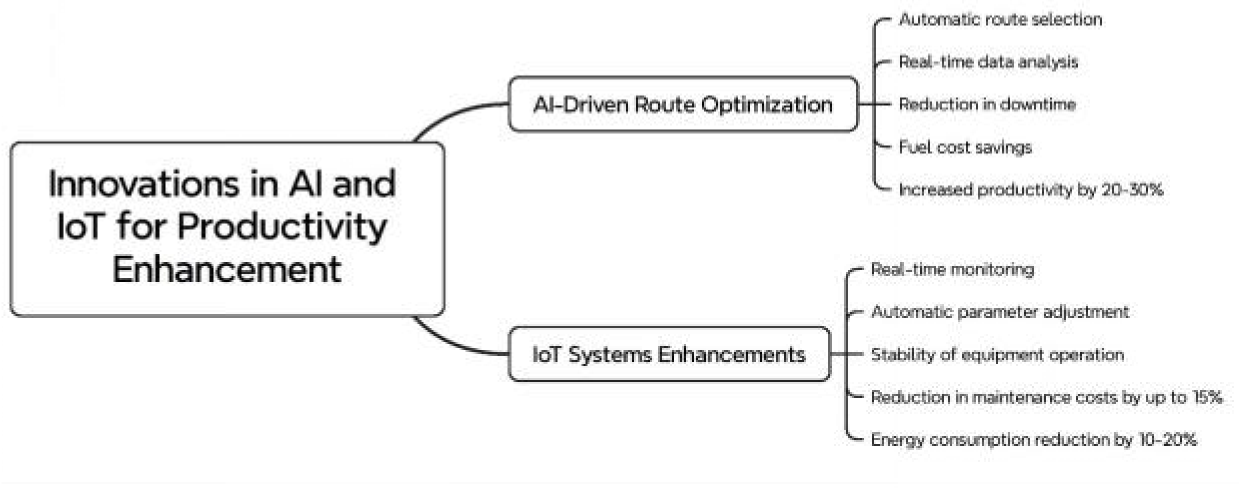

Figure 2. Optimising productivity through AI and IoT in machine and tractor units

IoT systems provide continuous monitoring and control of machinery in real time. They allow machines to automatically adjust operating parameters in response to changes in load, temperature, humidity and other variables. This not only ensures the stability of the machinery, but also helps to reduce the risk of breakdowns, extending the life of the equipment. It is estimated that such systems can reduce costs.

Thus, the integration of AI and IoT into the management of machine and tractor units opens up new opportunities for increasing productivity and safety, reducing the human factor and ensuring more efficient resource management.

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Lemets O. O.

DEPENDENCE OF DEEP VIBRATION CUTTING OF COHESIVE SOILS ON THE KINEMATIC PARAMETERS OF THE WORKING EQUIPMENT OF THE EARTHMOVING MACHINE

Scientific Advisor - Ph.D., Associate Professor Ragulin V.M.
Language Advisor – Cand. Ped. Sc., Assoc. Prof. Skrypnyk N. S.

Increased load when laying pipelines in a trenchless way, such as gas distribution networks, power cables, drainage systems, water supply and sewage networks, on equipment that performs these types of work. They are performed by special earthmoving machines, which are based on the formation of a deep gap in the soil with knife working organs. This process requires considerable traction. It is known that various methods of strengthening are used to reduce it, such as vibration, lubrication, machining and coating with anti-friction materials.

Thus, the issue of determining the influence of the intensification of deep soil cutting due to its kinematics is important on the strengthening process and has important scientific and practical significance.

The technology of trenchless laying of underground communications has been widely implemented in production and has been thoroughly covered in many studies by domestic and foreign authors.

The issues of laying pipelines and other types of engineering communications in various conditions, including mountainous and swampy areas, in an open manner and without trenching are presented in works (Ткачук, M. M. et all, 2013; Rudnev V. K., et all, 2015). They consider technologies for performing works, the principles of selecting a fleet of machines and mechanisms for carrying out earthmoving works.

From the analysis of trenchless technologies for laying pipelines, cables, and communication lines (Кравець С. В., et all, 2020), calculations were determined to determine the resistance to the laying of communications. It was established that for the implementation of the process, it is necessary to create a deep gap in the soil. For this, it is necessary to add significant forces to the knife working body to overcome the soil cutting resistance.

The process of intensification of deep soil cutting during trenchless laying of drainage systems for reclamation was considered in works (Кравець, С. В., et all, 2018; Suponyev, V., et all, 2021). The reduction of soil cutting resistance is achieved by increasing the critical depth of soil cutting with a multi-tiered knife and when the cutting depth is up to 1.2 m with a knife width of up to 40%. But this does not relieve the need to use an additional tractor, which in turn requires finding other ways to intensify the work process.

The purpose of the study is to develop scientifically based recommendations for reducing the resistance of deep cutting of the soil by the knife working body due to its vibrational and oscillatory movements. To achieve it, it is necessary to define the influence of the kinematics of the equipment of earthmoving machines on the process of vibrating soil cutting and set the value of the path and speed of movement of the knife working body at any moment in time t from the frequency of its oscillations, amplitude at fixed values of the speed of movement, the direction of oscillations is determined depending on the ratio of translational and vibrational velocities.

As is known, the general resistance of soils to deep cutting includes the following components: gravity of the cut soil; external and internal friction; resistance to separation of the soil from the massif.

The use of vibration shock oscillations of the vertical knife at a digging depth of up to 2 m for full-scale working bodies gives an even higher effect (60-95%), while only the vibration mode of oscillations allows you to reduce the traction force of the machine by only 35-48%.

At the same time, the effect of vibration in all considered cases increases due to an increase in the frequency and amplitude of forced oscillations. The total energy consumption of slitting with a vertical knife, in the author's opinion, slightly exceeds the energy consumption of static soil cutting.

Processing of experimental data using methods of mathematical statistics made it possible to acquire optimal values of the studied factors:

by traction power $\frac{nS}{\upsilon} = 888$;

by total power $\frac{nS}{\upsilon} = 465$,

where n is the number of revolutions of the vibration motor, rpm;

S is amplitude of slab oscillations, m;

υ is the speed of movement of the working body in the horizontal projection, m/s.

The back-and-forth movement of the plate affects the separated soil chips, which are, for example, in the middle of the scraper bucket. This, in turn, leads to a decrease in the friction between the soil and the soil, which makes it possible to reduce the traction force at the end of the filling phase by 25%.

At the same time, the dynamic loads on the traction-coupling device are reduced, the elements are crushed chipping of soil entering the bucket, and accordingly increases the total mass of soil filling in the working body ladle type (by approximately 10%); skidding of the car is reduced.

For a certain direction of oscillations depending on the translational ratio υ and vibrational $S\omega$ speeds, there can be two typical cases of interaction of the working body with the soil. Consider the option when $\frac{\upsilon}{S\omega} < 1$. At the same time, attention should be paid to the fact that the maximum value of the force at the moment of impact is reached at the highest value of the speed of the knife at the moment of "reaching" the ground, which should correspond to the single value of the speed of the machine at fixed vibration.

This fact has been established by many studies, the process of optimality of the value of the relationship $\frac{\upsilon}{S\omega}$ is achieved when its absolute values are smaller than one, i.e. at low translational speeds of the machine (Fig. 1).

A decrease in the feed rate simultaneously reduces the static cutting power ($P_{cm} \cdot \upsilon$), which can affect the total energy consumption of the process as a whole, taking into account the power consumption of the vibration drive.

Qualitatively, the graph of the influence of these dependencies on the resulting value can be presented in the following form (Fig. 2a). As can be seen from (Fig. 2b), the value of the resulting indicator will not always have a positive value (shaded area).

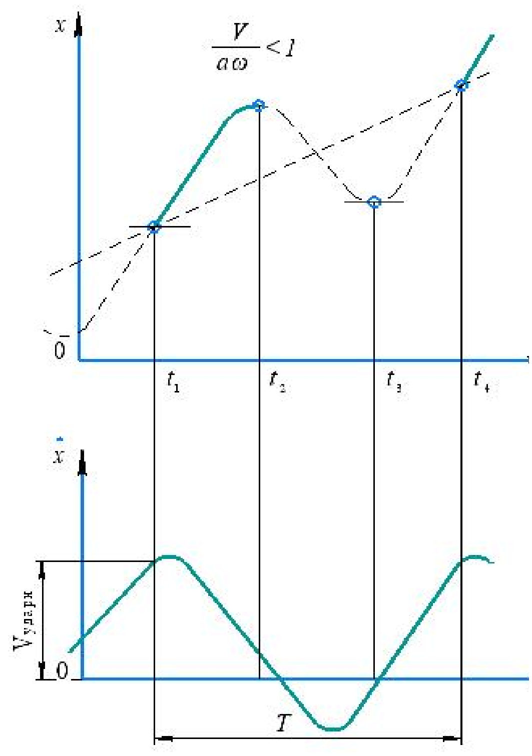
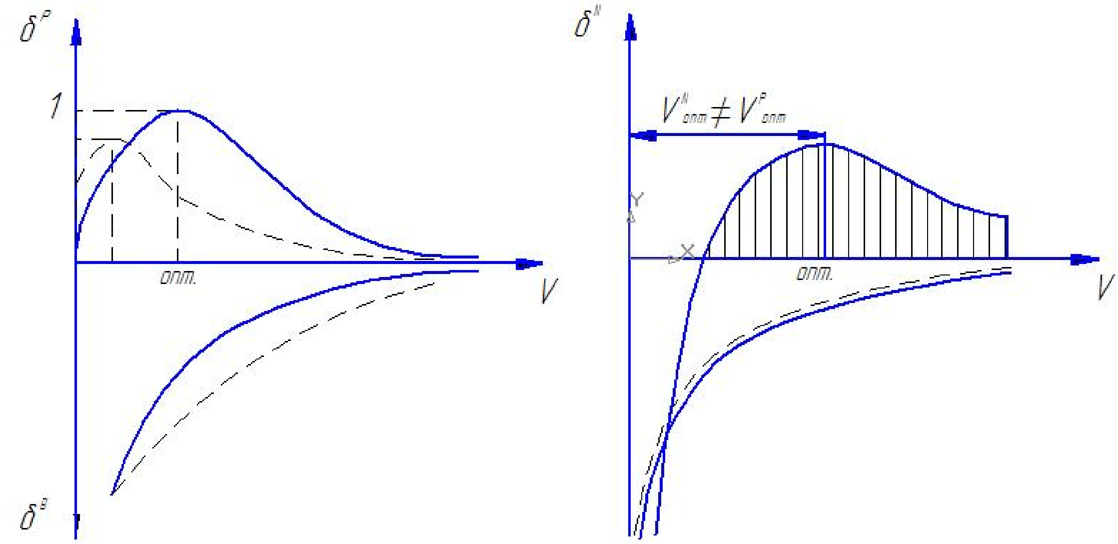


Figure 1. View of the knife path and speed graph under the condition: $\frac{\upsilon}{S\omega}<1$



a b

Figure 2. Energy efficiency of vibrating soil cutting:

a -components; b - resulting

According to the results of research on the influence of the kinematics of the working equipment of knife machines on the process of cutting soils was obtained as follows. The movement of the equipment when the ratio of the path and the speed of the knife is less than unity in some time segments, the cutting process in this case is similar to "chopping" with a frequency of blows equal to the frequency of the knife oscillations.

Analytical research on the known indicators of the effectiveness of the soil cutting process found that a decrease in the translational speed simultaneously reduces the static cutting power, which can affect the total energy consumption of the process as a whole, taking into account the power consumption for the drive of the vibration mechanism.

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Maiorova M. O.

USING COMPUTER SIMULATION IN INDUSTRIAL ENGINEERING: CURRENT CHALLENGES AND PROSPECTS FOR UKRAINE

Language Advisor – Asst. Prof. Chevychelova O. O.

The modern development of transport infrastructure serves as a foundation for economic growth, increased population mobility, and enhanced regional connectivity. This article examines the current state and future prospects for the development of Ukraine's transport infrastructure, the application of automated technologies in mechanical engineering, and the ways this knowledge can be integrated into the education and careers of master's students in mechanical engineering.

Much like the U.S. Interstate Highway System, which significantly contributed to economic growth and regional development, Ukraine's transport infrastructure has the potential to play a crucial role in improving the country's competitiveness and fostering integration with the European Union.

Ukraine possesses substantial potential for the development of its road network and transport logistics. Over the past decade, the Ukrainian government, supported by international partners such as the European Bank for Reconstruction and Development (EBRD), has invested in modernising road networks and constructing highways that link major cities and industrial centres with international transport corridors.

One noteworthy example is the "Great Construction" project, launched in 2020. This initiative focuses on reconstructing and building roads, bridges, and other critical transport infrastructure. According to Ukraine's Ministry of Infrastructure, over 6,000 km of roads were modernised, and 150 bridges were constructed in 2022 alone. These advancements contribute to reduced transportation times, lower transport costs, and improved road safety.

However, like the United States, Ukraine faces significant challenges, including rising construction material costs, economic volatility, and external pressures. Despite these obstacles, the country has made remarkable strides in modernising its transport infrastructure, as evidenced by the consistent growth in road repairs and improvements over recent years.

The following figure highlights these advancements by showing the total length of repaired and modernised roads in Ukraine from 2015 to 2022, underscoring the impact of increased investments and government initiatives, particularly through the "Great Construction" project. This data is derived from official reports of the Ministry of Infrastructure of Ukraine.

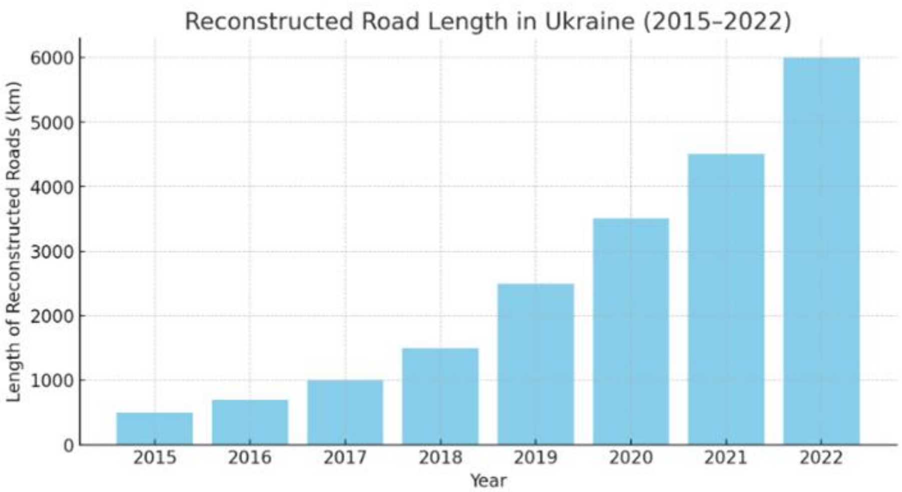

Figure 1 – Changes in the total length of modernised roads in Ukraine from 2015 to 2022.

Automated technologies are revolutionising industrial engineering, particularly in the operation of lifting and transport machinery, reclamation, and construction-road machinery. These innovations streamline and accelerate work processes, significantly improving efficiency and safety. Some of the key technologies include:

Machine Control Systems (MCS): These systems coordinate machinery operations using GPS and gyroscopes, enabling precise control and reducing errors. Automated excavators equipped with 3D navigation capabilities, for example, simplify tasks in complex terrains, minimising the need for manual intervention.

Intelligent Transport Systems (ITS): Widely used in traffic monitoring, management, and safety maintenance, ITS has proven to be effective in Ukraine. Over 100 surveillance cameras with automatic speed limit detection have been installed, contributing to a measurable reduction in accident rates.

Automated Infrastructure Condition Monitoring Systems (SCM): These systems continuously assess the condition of roads, bridges, and other critical infrastructure. Sensors installed on bridges and road surfaces detect changes in material structure, preventing accidents and ensuring timely maintenance. In Ukraine, SCM was successfully tested in Kyiv to monitor transportation hubs, improving road repair management efficiency and enabling proactive accident prevention.

These automated technologies are transforming industrial engineering by enhancing operational efficiency, reducing human error, and promoting safer infrastructure management.

Automated technologies have had a profound impact on the construction sector, streamlining operations and cutting down both costs and project timelines. The implementation of systems such as MCS, ITS, and SCM has enhanced accuracy, reduced human error, and allowed for more efficient use of resources.

Figure 2 illustrates the tangible benefits of these advancements, showing the reductions in work duration and associated costs within the construction sector from 2015 to 2022. The data highlights the role of automated systems in improving overall efficiency and underscores the value of integrating such technologies into industry practices.

The adoption of Automated Infrastructure Condition Monitoring Systems (SCM) has seen significant growth in Ukraine between 2015 and 2022. These systems, equipped with advanced sensors and detectors, have been increasingly installed to monitor the condition of roads and bridges, ensuring timely maintenance and accident prevention. Figure 3 illustrates the annual increase in the number of installed SCM devices, showcasing Ukraine's progressive approach to enhancing infrastructure safety and reliability through automation.

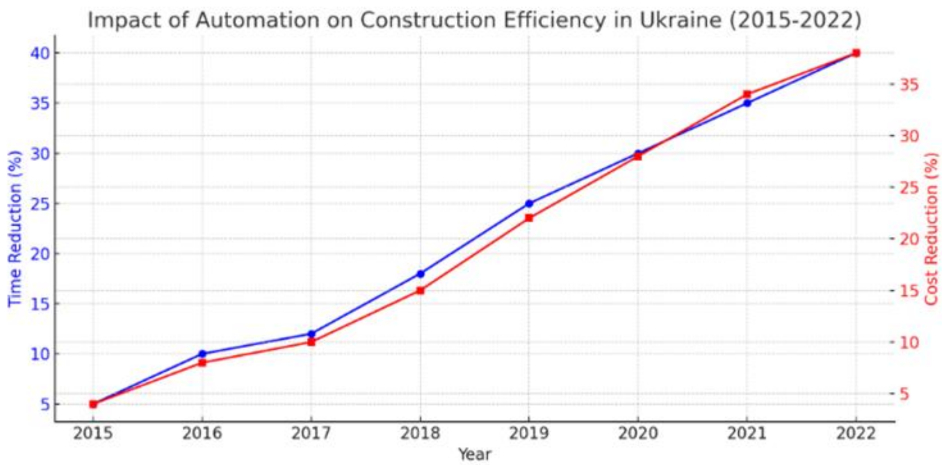

Figure 2 – Impact of automated technologies on construction sector efficiency (2015-2022)

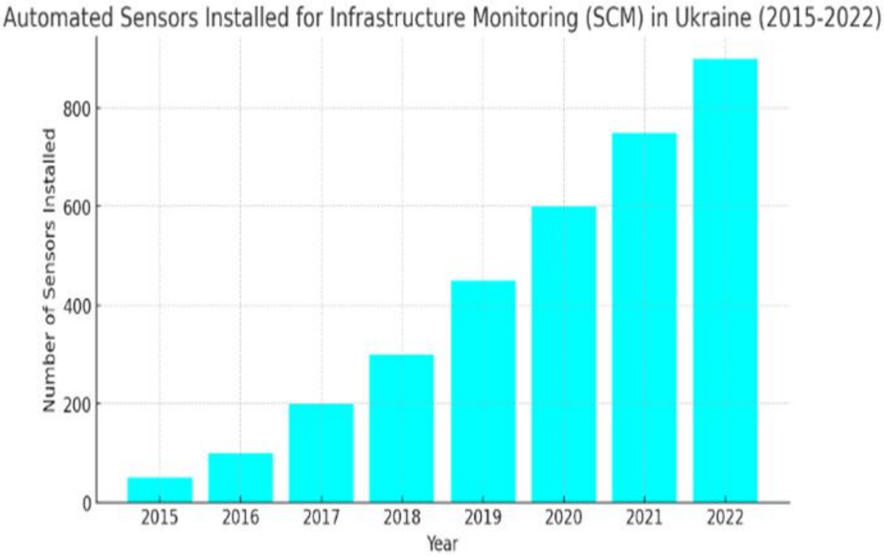

Figure 3 – Use of automated infrastructure condition monitoring systems (SCM) in Ukraine (2015–2022).

Figure 4 compares the use of advanced technologies in transport infrastructure across Ukraine, Poland, and Romania, focusing on project costs, timelines, and investment levels. This comparison highlights Ukraine's progress in modernization while also pointing out areas where Poland and Romania have more mature technology usage and established investment patterns. It offers valuable insights into the relative advancements of these countries and serves as a benchmark for Ukraine’s ongoing efforts.

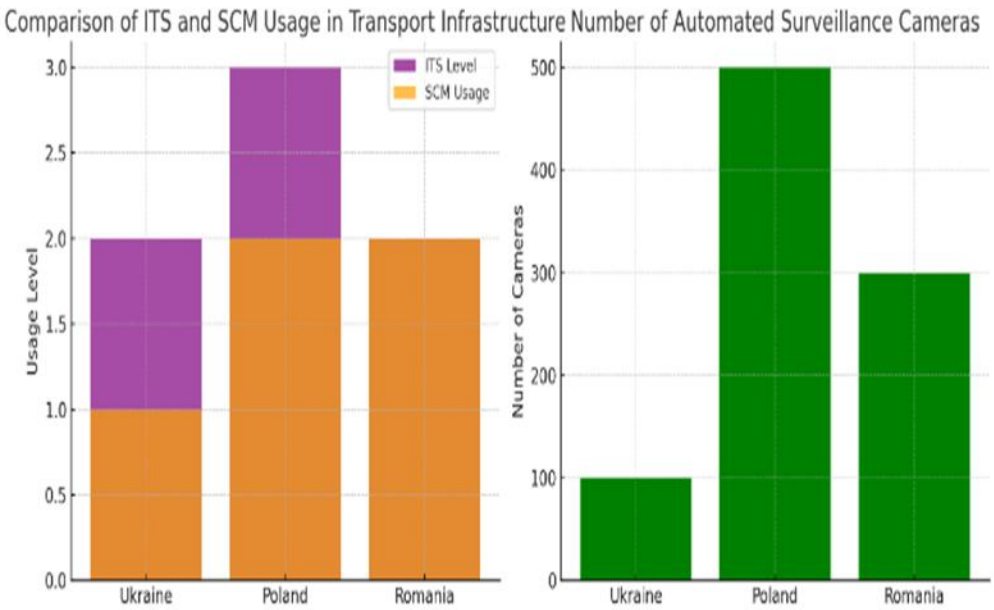

Figure 4 – Comparison of technology usage in transport infrastructure in Ukraine, Poland, and Romania

The development of transportation infrastructure and the implementation of automated technologies in mechanical engineering are crucial for the economic growth of Ukraine. The expansion and modernization of the transportation network, as demonstrated by the experience of the "Great Construction" project, significantly contribute to economic mobility and enhance safety levels.

In the future, additional investments in new technologies, such as intelligent transportation systems and autonomous construction machinery, will not only improve Ukraine's infrastructure but also elevate the level of automation in the mechanical engineering sector. Young specialists who are currently learning cutting-edge technologies in higher education institutions will play an important role in this process.

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Makogon A. A.

OVERVIEW OF RECENT RESEARCH ON HORIZONTAL DRILLING TECHNOLOGY

Scientific Advisor – Cand. Tech. Sc.. Assoc. Prof. Yefymenko O. V.
Language Advisor – Cand. Ped. Sc., Assoc. Prof. Skrypnyk N. S.

Horizontal directional drilling technology is a technology that ensures uninterrupted installation of communication cables and pipelines. This technology is currently developing quite rapidly. The relevance of this topic is growing due to the need to restore and build new underground communications that have been protected from the risk factors of destruction due to hostilities, as well as artillery and missile attacks from the aggressor country.

The advantages of using horizontal directional drilling are not only its high efficiency, environmental protection and reduction of excavation work, but also reliability and safety in the further operation of communications laid through the well. In our present day, this technology is becoming increasingly important for defense infrastructure projects, both for the protection of the civilian population and for military purposes.

Modern researchers (Wang, 2024) pay attention to the development of additional factors affecting drilling time. That is, not only the classical factors of friction, contact pressure, etc., but also add, for example, the drilling fluid pressure factor. Using the contact factor of the pipe with the well wall, the researchers propose a new model of the pull-out load. Taking into account the additional effects of the impact and fluid resistance for the drilling fluid, the scientists proposed more accurate calculations of the pipeline separation load and compared them with the results of field studies. Which makes it possible to become a useful tool for analyzing the pipe-well wall contact and reverse load for horizontal directional drilling. Another area of research was the study of drilling trajectory planning. Which in practice is actually built by trial and error based on the previous design trajectory. The standard path of horizontal drilling can be described as follows: "straight section - curved section - horizontal section - curved section - straight section". The researcher (Jin, 2022) proposed a “catenary network” design method, with the advantage of less friction during drilling. This design method uses a radial motion optimization algorithm. In addition, like the previous researcher, the drilling fluid pressure is taken into account. After verification in practical application, this approach has shown its promise.

Scientists pay attention to solving the problem of large-section drilling. During construction, the bending deformation and large support moment of the drill string are key problems that limit the development of horizontal drilling technology.

Analysis shows that when the bending deformation is small, priority should be given to reducing friction and torsion at the bending position. Excessive thrust at the inlet is the main cause of bending deformation, and the smaller the hole diameter, the more serious the bending deformation. Strong bending deformation will lead to an increase in the frictional resistance in the deformed part and even local self-locking, which will make it impossible to continue to increase the weight on the drilling working body. The results of the study (Tong, 2022) reveal the relationship between bending deformation and support torque in hard disk engineering at upper distances (several kilometers) and indicate the law of the appearance of support torque and bending deformation, which is of reference value for the development of horizontal drilling technology.

Scientists are looking for new and improved technical means to overcome existing drilling problems. For example, to solve the problem of cleaning the well from drilling cuttings, researchers (Ju, 2022) propose to use a new type of elliptical-shaped drill pipe during horizontal well drilling. Due to the flow turbulence and secondary flow caused by the rotation of the curved wall, the phenomenon of fluctuation of the distribution of drilling cuttings along the direction of rotation of the drill pipe was observed and the cuttings transportation ability was enhanced. The use of elliptical drill pipe as a hinge-type tool can improve the efficiency of hole cleaning. Under the optimal conditions used in this study, the efficiency of hole cleaning increased by almost 18%.

Many authors of studies on the topic of horizontal drilling pay attention to solving the problem of ecology, namely, reducing the negative impact on the environment of drilling waste. The areas of such research include the application of the technology of loss-free use of drilling fluid (Kwast-Kotlarek, 2018) and the impact of one loss of drilling fluid on living beings.

One of the modern areas of scientific research is the application of artificial intelligence to solve scientific and practical problems. The topic we are considering has not become large. The authors of the study (Krechowicz, 2021) analyzed more than a hundred horizontal directional drilling projects and developed machine learning models and applied an artificial neural network to predict the overall project outcome of error-free installation and the occurrence of detected undesirable events. The best indicators of memorization and accuracy were achieved for the developed model, which turned out to be effective, fast and reliable in predicting risks in horizontal drilling projects. The use of machine learning in the proposed models made it possible to eliminate the involvement of a group of experts in the risk assessment process and, thus, significantly reduce the costs associated with the risk assessment process. Further research can be aimed at developing a comprehensive risk management system that will allow for dynamic risk assessment taking into account various combinations of risk reduction actions.

A brief overview of the solution of modern horizontal directional drilling problems by scientists demonstrates their different directions and approaches to this issue. The application of scientific calculations and research provides more data for the development of this technology and, possibly, will simplify the drilling process. The combination of scientific research with practical application will push for the improvement of drilling tools and methods and rules for performing drilling work. This aspect can become one of the important ones for the installation of underground communications, which provide and service not only the usual above-ground buildings, but also special underground structures, such as civilian shelter facilities, for example, underground schools and other educational institutions, hospitals, administrative service centers, bomb shelters, etc.

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Orlov N. A.

ZMIIVTHERMAL POWER PLANT'S DESTRUCTION: A MAJOR SETBACK FOR UKRAINE'S ENERGY SECTOR

Language Advisor – Senior Lecturer Ivanova I.L.

Zmiiv Thermal Power Plant (TPP) was one of the most important energy assets in Ukraine, playing a critical role in ensuring the energy stability and economic development of the region. Located in the Kharkiv region, Zmiiv TPP occupied a significant place in the country's energy sector, providing both local residents and industrial enterprises with the necessary amount of electricity and heat.

The construction of Zmiiv Thermal Power Plant began in the 1960s, during the period of active development of the energy infrastructure of the USSR. The station was built as part of a project to meet the growing energy needs of eastern Ukraine and to cover the increasing demand for energy resources due to the rapid industrialization of the region.

Zmiiv TPP was officially commissioned in 1967. It underwent several modernizations, implementing the latest technologies that allowed it to remain competitive in the energy services market.

Zmiiv TPP was one of the largest thermal power plants in Ukraine. The plant's total installed capacity was about 2,600 MW. It consisted of several power units that operated on coal supplied from various mines across the country. Notably, Zmiiv TPP was a thermal power plant that produced both electricity and heat for district heating systems.

The plant consisted of six power units, each with a capacity of 300 MW. To ensure the effective operation of the station, a number of technological innovations were implemented. For example, the modernization of boiler units and turbines, as well as the improvement of flue gas systems, helped reduce the environmental impact. In the 2000s, several projects were undertaken to upgrade the turbines and boilers, significantly increasing the plant's efficiency and reducing harmful emissions.

In addition, the plant implemented programs to increase its energy efficiency, particularly by using cogeneration units that allowed it to simultaneously produce both electricity and thermal energy with the maximum use of fuel resources.

Zmiiv TPP was one of the key components of Ukraine’s energy system. It provided a stable supply of electricity to the vast territories of eastern Ukraine, particularly the Kharkiv region. During peak loads, especially in the winter period, Zmiiv TPP played a crucial role in balancing the energy demand, stabilizing the energy situation in the region.

The plant was part of the "Ukrenergo" energy system and could operate in synchronization with other energy sources to ensure a balance between supply and demand in the energy market. Zmiiv TPP also played an essential role in supplying hot water to large industrial enterprises, as well as residential and municipal facilities in Kharkiv and the surrounding areas.

Despite its importance for energy stability, the operation of Zmiiv TPP had a certain environmental impact. The plant ran on coal, which was one of the main pollutants of the environment. The power plant emitted significant amounts of carbon dioxide (CO2), sulfur dioxide (SO2), and other harmful substances, contributing to air pollution and affecting public health.

To mitigate the environmental impact, Zmiiv TPP continuously implemented measures to reduce emissions. They included the installation of modern flue gas cleaning systems, upgrading boilers and turbines, and developing alternative energy sources, such as solar and wind energy, to reduce dependence on coal. In recent years, the flue gas filtration systems were significantly upgraded, which helped reduce the plant's emissions of harmful substances into the atmosphere.

Another key aspect was the transition to more environmentally friendly fuel types, including biomass, as an alternative to coal. This shift helped reduce the environmental burden and lowered CO2 emissions.

Zmiiv TPP, like many other energy facilities in Ukraine, faced a number of challenges related to outdated equipment, environmental concerns, and the need to adapt to changing energy realities.

Zmiiv Thermal Power Plant was a strategically important element of Ukraine’s energy infrastructure, providing stable electricity and heat to large territories in the eastern part of the country. However, to maintain its efficiency and minimize its environmental impact, the plant needed to continue its modernization efforts and adopt new technologies while also utilizing alternative energy sources. By doing so, Ukraine could have ensured the sustainable development of its energy sector and maintained environmental balance for future generations.

On September 11, 2022, the station, along with several other Ukrainian energy infrastructure facilities, was bombarded, resulting in a fire. On March 29, 2024, the "Ukrenergo" announced that Zmiiv Thermal Power Plant had been entirely destroyed in a Russian missile strike.

Io conclude, attention should be drawn to the fact that the destruction of Zmiiv Thermal Power Plant marks a significant blow to Ukraine’s energy infrastructure, highlighting the vulnerabilities of critical facilities amidst ongoing conflict. As one of the most vital energy assets in the eastern region, the plant not only provided electricity and heat to millions but also played a central role in balancing the national energy supply. The loss of the Zmiiv Thermal Power Plant further amplifies the need for rapid modernization and diversification of energy sources. With determination and innovation, Ukraine can overcome these challenges, paving the way for a more sustainable and resilient energy landscape for future generations.

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Panchenko M.M.

HYBRID CARS: PERFECT BALANCE OF EFFICIENCY, PERFORMANCE AND ECO-FRIENDLINESS

Language Advisor – Senior Lecturer Ivanova I.L.

Hybrid cars are becoming increasingly popular. They combine an internal combustion engine (ICE) and an electric motor, offering the benefits of both technologies. With rising fuel prices and a trend towards eco-friendliness, hybrids are a good compromise between traditional cars and electric vehicles.

A hybrid car operates through a complex process involving several stages, each utilizing different systems to ensure maximum efficiency, economy, and environmental friendliness. These stages interact in a way that optimally uses the energy of both the internal combustion engine (ICE) and the electric motor r.

During the start-up stage and when driving at low speeds, the car runs exclusively on the electric motor. This minimizes fuel consumption and completely eliminates emissions of harmful substances. The electric motor ensures a smooth start and movement at low speeds, such as when leaving a parking lot or navigating a city traffic jam.

As the speed increases, the internal combustion engine comes into operation. The electric motor continues to function, but the ICE takes on the main load. At this point, excess energy produced by the engine can be accumulated in the battery, which ensures its subsequent use in less energy-intensive modes.

During intensive acceleration, for example, when overtaking or climbing a hill, the main power is provided by the ICE, which operates at full capacity. The electric motor performs an auxiliary function, maintaining the vehicle's dynamics and improving acceleration characteristics. This combination allows for high performance without significantly increasing fuel consumption.

When the vehicle slows down or comes to a complete stop, the electric motor switches to generator mode, converting kinetic energy into electrical energy. This process, known as energy recovery, allows the battery to be charged without the need to be connected to an external power source. Recovery is especially effective in urban areas, where frequent stops and braking are common.

The type of hybrid vehicle directly affects the operation of these systems. Micro hybrids use electrical energy exclusively for auxiliary functions, such as starting the engine and braking support. Micro hybrids are not equipped with a full-fledged electric motor, so they cannot move only on electricity, but they provide a reduction in fuel consumption through the use of a start-stop system.

In mid-hybrids, the electric motor complements the work of the internal combustion engine, increasing overall power and improving fuel efficiency. However, their electrical system is not powerful enough to move exclusively on electricity, which limits their functionality.

Full hybrids are the most technologically advanced hybrid vehicles that can operate entirely on electricity, without the need to start the internal combustion engine. This mode is especially convenient for short trips around the city, where the electric motor provides economical and environmentally friendly movement. If necessary, full hybrids automatically switch to a combined mode or completely on the internal combustion engine, which makes them a universal solution for any operating conditions.

Hybrid cars are an innovative combination of technologies that achieve a perfect balance between fuel economy, environmental friendliness and performance. The choice of the hybrid type depends on the individual needs of the owner: ranging from minimal reliance on electricity to the full use of the electric motor in everyday operation.

Hybrid cars offer a significant number of advantages that make them attractive to modern drivers who seek efficiency, eco-friendliness and comfort. These vehicles successfully combine the best qualities of cars with an internal combustion engine and electric cars, providing unique advantages that distinguish them from other types of cars.

One of the key advantages of hybrids is fuel economy. Thanks to a well-thought-out system of interaction between the ICE and the electric motor, hybrid cars consume 25% less fuel compared to conventional ICE cars. This is especially noticeable in urban conditions with frequent stops and starts, where the electric motor takes on the main load. For hybrid owners, this means not only lower operating costs, but also less dependence on fuel prices.

Environmental friendliness is another important advantage. Hybrids emit significantly less carbon dioxide and other harmful substances into the atmosphere due to the reduced operation of the ICE at low speeds or when driving on electricity. This makes them an ideal choice for environmentally conscious drivers, as well as for regions where strict restrictions on vehicle emissions are introduced.

An important advantage of hybrids is their silence. In electric mode, such cars make virtually no sound, which makes the ride comfortable for both the driver and passengers, as well as for those around them. This is especially important in urban areas, where noise pollution is becoming an increasingly acute problem. For many drivers, this feature of hybrids is one of the reasons for choosing them.

A large power reserve is also what distinguishes hybrid cars. Even if the fuel tank is empty, a full hybrid can continue moving using the electrical energy stored in the battery. This provides flexibility when traveling, especially if there is no gas station nearby, and minimizes the risk of the car stopping completely due to lack of fuel.

One of the unique features of hybrid cars is energy regeneration. Regenerative braking technology allows the kinetic energy generated during braking to be converted into electrical energy. This energy is used to recharge the battery, increasing the driving range and improving the overall efficiency of the car. In the urban cycle, where frequent stops are the norm, this process becomes especially effective. Hybrid cars combine advanced technologies, providing both practical benefits and a contribution to environmental protection. They are the optimal solution for those who value economy, ecology and innovation, providing the opportunity to use modern technologies for the benefit of comfort and conservation of natural resources.

Disadvantages of hybrid cars:

High price (Hybrid cars are significantly more expensive than traditional cars, often costing up to 50% more);

Expensive repairs (Maintenance and repairs can be costly as they require specialized knowledge and trained professionals);

Battery degradation (Over time, the batteries in hybrid cars lose their capacity and efficiency, leading to reduced performance);

Limited electric range (The electric mode is generally suitable only for short-distance trips, which can be a limitation for some users):

Weight and capacity (The additional equipment, such as the battery and electric motor, increases the vehicle's weight and reduces available cabin space).

Hybrid cars continue to occupy an important place in the market, offering the perfect balance between performance, economy and eco-friendliness. Experts from the British publication Autoexpress tested various models and identified the top ten, each of which deserves attention.

Mercedes S 58 e. This executive car continues to set the standards for luxury and technology. Its 3.0-liter six-cylinder petrol engine and 148 hp electric motor together produce 510 hp. The 21.5 kWh battery allows for up to 110 km of electric driving, and charging to 80% takes only 20 minutes. This is the ideal choice for those who value luxury and eco-friendliness.

DS 4 E-Tense 225. The French hybrid stands out with its improved transmission. With a combined output of 222 PS from its 1.6-litre engine and electric motor, the DS 4 E-Tense 225 accelerates to 100 km/h in 7.7 seconds. T It offers an electric range of 65 km and serves as a worthy rival to models like the Audi A3 TFSI e.

Range Rover Sport P460e. This sporty SUV boasts a sophisticated design and high performance. Its hybrid setup includes a 3.0-litre six-cylinder engine and a 38.2 kWh battery, providing a theoretical electric range of up to 125 km (in reality, around 80 km). It accelerates from 0 to 100 km/h in just 5.3 seconds.

Skoda Octavia iV. Practicality and space make the Octavia a popular choice. Its 1.4-liter turbocharged engine and electric motor produce 201 hp, allowing it to accelerate from 0 to 100 km/h in 7.8 seconds. The battery provides an electric range of 70 km, making this car efficient for everyday trips.

Toyota RAV4. The legendary hybrid from Toyota is known for its efficiency. It uses only 0.83 liters of fuel per 100 km (under ideal conditions) and travels up to 75 km on electricity. Although the interior design is quite conservative, it fully meets the needs of modern drivers.

Suzuki Across. This hybrid is an affordable alternative to the Toyota RAV4. Its 2.5-liter gasoline engine and 18.1 kWh battery provide 75 km of electric range. The Across is equipped with all-wheel drive, making it a versatile choice for any road conditions.

Kia Sportage PHEV. Kia's mid-size crossover impresses with its performance and stylish design. The 261-horsepower hybrid system accelerates from 0 to 100 km/h in 8.2 seconds. The electric range is 70 km, and the interior features two 12.3-inch displays.

Lexus NX 450h+. Sleek and dynamic, this hybrid combines power and comfort. Its electric range is 65 km. The Lexus NX stands out with the brand's best infotainment system and excellent build quality.

BMW 330e. BMW's classic station wagon has become even better in a hybrid version. The combination of a 2.0-liter engine and an electric motor provides high performance, although the 10.5 kWh battery reduces trunk space. The new dual-screen interface makes driving even more convenient.

Mercedes C 300 e. This hybrid version of the C-class can travel up to 110 km on a single battery charge, which makes it ideal for daily trips. The modern MBUX system with an 11.9-inch screen ensures ease of operation, and high-quality interior materials emphasize the premium character of the model.

Summarizing the above, it can be concluded that hybrid cars are a combination of innovation and practicality. They offer fuel economy, environmental friendliness, and technological advantages. Despite the disadvantages, such cars remain a popular choice, especially in the context of rising energy prices. Choosing a hybrid is an investment in a comfortable future and care for the environment.

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Pashkov V.G.

NEW STRATEGY OF BMW GROUP

Language Advisor – Senior Lecturer Ivanova I.L.

For over a century, BMW Group has consistently reinvented itself. As a leader in the field of advanced technologies, the company has transformed both the automotive industry and the world of personal mobility.

BMW Group supports the idea that all changes in the automotive world driven by the development of digital data transmission technologies provide an excellent opportunity to make the driving experience simpler, safer, and more comfortable, which is particularly appealing to new customers. In the coming years, the company will focus on expanding its technological potential and creating an even closer connection between people, vehicles, and various services.

The focus of technical development will be on gradually achieving new goals in the fields of electrified transport and autonomous driving. BMW Group has reinforced its status as an innovator and strategically oriented manufacturer of innovations through its BMW I sub-brand, which has already delivered over 50,000 vehicles, as well as with the latest generation of its flagship sedan, the BMW 7 Series. BMW iNEXT is a symbol of technological excellence.

Over the next 10 years, the new BMW Group strategy will materialize in a revolutionary new BMW I model, which will elevate personal mobility to an unprecedented level. The BMW iNEXT model will drive the development of new types of automated driving and a unified digital network, alongside a new generation of electric vehicles, innovative lightweight constructions, and modern interiors. These elements will set new standards that will become key criteria for customers evaluating vehicles in the future.

BMW I's leadership in advanced technologies is already reflected in the growing electrification of other models. The third generation of modern Plug-in hybrid models is a technological pioneer in the market. In the fourth generation, the electric vehicle lineup will expand, and the fifth generation, marking further advancements in all aspects, is already in development. This technological exchange will serve as the foundation for BMW iPerformance Plug-in hybrid models.

Since 2016, BMW Group has developed seven different models that either have a fully electric drive, like the BMW i3, or combine an internal combustion engine with an electric drive in Plug-in hybrid formats. In the coming years, entirely new vehicles will be introduced, including a Plug-in model from MINI, as well as the innovative BMW i8 sports car, which has won numerous awards and will feature an open-top version. Additionally, by the end of 2016, the BMW electric vehicle lineup was expanded with a BMW i3 model equipped with higher-capacity batteries and extended range.

Additionally, BMW Group continues to advance in the field of hydrogen technology; current test vehicles have achieved a range of up to 700 km. The company adheres to the philosophy that multiple types of powertrains will coexist in the future. This outlook is fully reflected in the company's current vehicle designs, which incorporate all classic and alternative powertrains.

The I 2.0 project ensures BMW's leadership in autonomous driving. BMW Group's progress in the electric vehicle segment is largely due to the success of the I project, which established the company as an innovator in eco-friendly transportation.

Project I allowed the company to gain early experience in electric vehicle development and lay the foundation for large-scale production. Thanks to I 2.0, BMW Group is now embarking on an equally ambitious path in autonomous driving and full integration into a unified network.

Harnessing the potential of digital technologies, BMW Group is strengthening its leadership in this field. The primary focus will be on high-precision electronic maps, sensor and cloud technologies, and artificial intelligence, which are key to success in this segment. BMW Group's investments in these services have already provided access to high-precision maps.

"Our main direction is to assert the position of BMW Group as a technological leader in the market," said Klaus Fröhlich, member of the Board of Directors of BMW AG, responsible for development. "With the I 2.0 project, we are leading the management of autonomous driving. We are transforming research projects into new production formats and bringing the future to public roads."

Since the launch of the new flagship BMW 7 Series in October 2015, customers have been able to experience a new level of advanced autonomous driving technologies and unmatched premium vehicle quality. This flagship of the BMW Group is equipped with a stereo camera and five radar detectors, allowing it to stay in its lane and automatically maintain a safe distance at speeds of up to 210 km/h. The BMW 7 Series is also capable of parking itself in a garage thanks to the remote control parking feature, which is available through the interactive BMW display key.

The gesture control functions and comprehensive communication have made the BMW flagship a benchmark in user interfaces and digital innovations. To further strengthen its leadership in autonomous driving, BMW Group plans to implement these technologies in other models over the coming years. New sensor developments and more powerful software will ensure rapid progress in the world of autonomous vehicles, with the BMW iNEXT as a reference point. Digital technologies enhance the driving experience for customers.

BMW Group has also quickly recognized the dynamic importance of other electronic services by introducing products such as DriveNow, ParkNow, and ChargeNow—key elements for the company's future success. This year, BMW Group will announce the next steps to enhance these services. In addition to its own developments, BMW Group invests in a number of promising startups and service providers through the BMW I Ventures fund. This division helps the company identify new trends and respond to them swiftly. This provides a significant advantage, as the development cycle in the IT sector is considerably shorter compared to the automotive industry.

Modern technologies and digital services are transforming the business environment. However, the long and capital-intensive investment cycles inherent in this industry, as well as the lengthy product life cycles, indicate that these changes cannot happen overnight. BMW Group hopes that over time this transformation will occur more rapidly, but, overall, it will remain a lengthy process. This is clearly reflected in the architecture of the current BMW Group models, which include vehicles not only with traditional internal combustion engines but also with alternative powertrains.

New models from BMW, BMW M, MINI, and BMW Motorrad. To achieve sustained success, the BMW brand aims to further strengthen its flagship models with the new BMW X7. Additionally, there are plans to expand the BMW M lineup soon and launch a powerful M Performance version for the most popular models. The company continues to explore the potential of these attractive high-profit segments.

Building on its comprehensive strategy, the motorcycle division of BMW aims to ensure profitable and sustainable growth in the coming years. The strategic goal is to sell 200,000 motorcycles by 2020. As part of the new product strategy, BMW Motorrad also plans to target the affordable motorcycle segments with engines under 500 cc, primarily through the new BMW G 310 R model.

In conclusion, it should be noted that values are an important factor in corporate success. Any strategy would be meaningless without the right people responsible for its implementation. This is why BMW Group is confident that, alongside technical progress, the proper development of corporate culture and leadership culture plays a crucial role in shaping future changes in the world of personal mobility.

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Pavlenko M.Y.

HYBRID CARS

Language Advisor – Asst. Prof. Vorobyova S. V.

The integration of hybrid technology into automobiles has revolutionized the automotive industry, blending the advantages of internal combustion engines with electric propulsion systems. Hybrid vehicles offer improved fuel efficiency, reduced emissions, and versatile performance, making them an attractive option for modern transportation needs.

The Concept of Hybrid Cars

A hybrid car combines two distinct power sources: a traditional internal combustion engine (ICE) and an electric motor powered by batteries. This dual powertrain enables the vehicle to optimize energy usage depending on driving conditions, switching between or combining power sources for maximum efficiency. Hybrid systems generally fall into three categories:

- Series hybrids: The electric motor drives the wheels, and the ICE serves as a generator to produce electricity.
- Parallel hybrids: Both the ICE and electric motor can simultaneously power the vehicle.
- Plug-in hybrids (PHEVs): A subcategory that allows batteries to be charged via an external power source, offering extended electric-only range.

Key Features of Hybrid Cars

1. Energy Recovery: Hybrid cars utilize regenerative braking to convert kinetic energy into electrical energy, which is stored in the battery for future use.
2. Start-Stop Technology: The ICE shuts off when the vehicle is idle, reducing fuel consumption and emissions.

3. Modes of Operation: Hybrid vehicles can operate in electric-only mode, ICE-only mode, or a combination of both depending on speed, load, and driving conditions.

Toyota Prius: A Pioneer in Hybrid Technology

The Toyota Prius, introduced in 1997, is considered the first mass-produced hybrid car. Its powertrain combines a 1.8L gasoline engine with an electric motor and a continuously variable transmission (CVT). The Prius exemplifies the advantages of hybrids, offering significant fuel economy and low emissions.

The car's hybrid synergy drive allows seamless transitions between power sources and adjusts energy allocation dynamically. The regenerative braking system and aerodynamic design further contribute to its efficiency.

Toyota prius

Advancements in Hybrid Technology

Several automakers have enhanced hybrid systems by incorporating cutting-edge technology:

- Honda's Integrated Motor Assist (IMA): This system uses a compact electric motor to assist the ICE during acceleration, improving performance and efficiency.
- Ford's Hybrid System: Found in models like the Ford Fusion Hybrid, it integrates electric motors for smooth driving transitions and enhanced fuel economy.
- Plug-In Hybrid Innovations: Vehicles such as the Chevrolet Volt and Toyota Prius Prime offer greater electric-only range and charging flexibility.

Benefits of Hybrid Cars

1. Environmental Impact: Hybrid cars produce fewer greenhouse gas emissions compared to conventional vehicles, contributing to cleaner air and reduced dependence on fossil fuels.
2. Cost Savings: While initial purchase costs may be higher, hybrid cars provide long-term savings through lower fuel consumption and maintenance costs.
3. Performance: Modern hybrids deliver smooth acceleration, quieter operation, and adaptive driving modes, enhancing overall driving experience.

Challenges and Future Prospects

Despite their benefits, hybrid cars face challenges such as high manufacturing costs, battery disposal concerns, and limited electric range in certain models. However, ongoing advancements in battery technology, government incentives, and consumer awareness are driving the adoption of hybrid vehicles.

The future of hybrid cars lies in the development of lighter, more efficient batteries and integration with renewable energy sources. With increasing environmental concerns and stricter emission standards, hybrid technology is poised to play a vital role in shaping sustainable transportation.

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Poddubnyi I. V.

IMPACT OF TECHNOLOGY ON ENERGY EFFICIENCY IN TRANSPORTATION

Language Advisor – Senior Lecturer Ivanova I.L.

The transportation sector, as one of the largest contributors to greenhouse gas emissions, has been a focal point for implementing sustainable technologies. Energy-efficient transportation is no longer a luxury but a necessity as countries strive to meet international environmental standards. This paper explores advancements such as electric vehicles (EVs), connected and autonomous vehicles (CAVs), renewable energy integration, and eco-driving practices that significantly influence transportation energy efficiency (Chen, Y., Li, M., 2024; European Commission, 2017).

Electric vehicles are at the forefront of energy-efficient transportation technologies, offering a cleaner alternative to traditional fuel-powered vehicles. EVs operate on electric power, eliminating tailpipe emissions and reducing overall carbon footprints. Battery technology has seen considerable advancements, from lithium-ion to emerging solid-state and lithium-sulfur batteries, which enhance energy density, range, and charging speed (Chen, Y., Li, M., 2024). Recent innovations include regenerative braking systems that capture and convert kinetic energy into stored battery power during braking. Additionally, wireless charging systems are now being tested, allowing EVs to charge while in motion, increasing efficiency without disrupting transport flow (Patel, R., 2023).

One major challenge is the energy demand placed on electrical grids by widespread EV adoption. Smart grid integration allows for demand-responsive charging, meaning EVs can charge during off-peak hours or when renewable energy sources are abundant. This reduces the risk of grid overload and lowers costs associated with energy production (European Commission, 2017). Policymakers and city planners are working on expanding charging infrastructure, which includes both fast-charging stations and in-home options for improved accessibility and convenience.

Connected and autonomous vehicles (CAVs) hold transformative potential for energy efficiency. CAVs use technologies such as vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication to optimize traffic patterns, reduce congestion, and smooth driving behavior, all of which contribute to fuel savings. Studies indicate that fully autonomous driving, once widespread, could improve fuel efficiency by up to 20% in mixed urban traffic settings (Garcia, M., 2023).

In cities, for instance, CAVs can automatically adjust speeds to meet real-time traffic conditions, which reduces idling times and energy use during peak hours. These vehicles are programmed to follow eco-driving principles that maximize fuel efficiency through smooth accelerations, minimal braking, and route optimization. As technology advances, integration of machine learning algorithms allows CAVs to learn and predict optimal routes, adapt to changing road conditions, and avoid traffic-heavy areas, further enhancing energy efficiency (Lin, H., Kumar, S., 2023).

A key element in increasing transportation energy efficiency is incorporating renewable energy sources. Charging stations powered by solar, wind, or hydropower reduce reliance on fossil fuels, making EVs an even more sustainable choice. Solar-powered buses, electric ferries, and hydrogen fuel cells for heavy-duty trucks are increasingly common across cities with aggressive carbon-neutral targets. Studies show that renewable integration can reduce energy costs and lower emissions by up to 30% for electric-powered fleets.

In line with renewable integration, storage technology advancements play a critical role. High-capacity batteries, such as lithium-air and solid-state batteries, are being developed to support long-distance EVs. In public transportation, buses and trains now use large-scale batteries for efficient long-term storage of solar energy collected during the day, which can then be used at night. Grid-connected systems also allow for energy sharing, where excess power generated by renewables can be stored and later distributed to the grid or directly to vehicles in need of charging (European Commission, 2017).

Eco-driving techniques are simple yet effective methods for reducing energy consumption. These practices involve driving behaviors such as steady acceleration, maintaining consistent speeds, and avoiding rapid braking. Eco-driving technologies integrated into CAVs and other smart vehicles analyze real-time driving data to recommend adjustments that minimize fuel use. For electric vehicles, eco-driving can extend battery life by reducing the need for frequent recharging (White, K., 2024).

Another critical aspect of energy-efficient transportation is vehicle design. Lightweight materials, such as carbon fiber composites and aluminum, are replacing steel to reduce vehicle weight, making it easier for engines (or motors, in EVs) to maintain speeds with less energy. Improved aerodynamics, especially for long-haul trucks and buses, also reduces drag, which is especially beneficial at highway speeds. These advancements have shown energy efficiency improvements of up to 15% in fuel-based vehicles and further enhance range and performance for EVs (Chen, Y., Li, M., 2024).

Governments and industry leaders play essential roles in facilitating these advancements through incentives, regulations, and investments in infrastructure. Policies promoting the construction of smart-charging networks, investments in renewable-powered public transport, and support for research on battery recycling are driving the shift toward an energy-efficient transportation system (European Commission, 2017). Incentives for adopting EVs and CAVs, as well as subsidies for installing renewable energy sources at charging stations, are further accelerating adoption and creating a sustainable transport future.

In conclusion, it should be highlighted that technology's impact on transportation energy efficiency is multifaceted, involving the development of EVs, CAVs, renewable integration, lightweight designs, and smart infrastructure. These innovations not only reduce energy consumption but also decrease emissions, supporting global efforts to mitigate climate change. While challenges in infrastructure, grid capacity, and initial costs remain, ongoing advancements and government support promise a future where transportation is both energy-efficient and environmentally sustainable.

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Poliakov Y. S.

DEVELOPMENT OF A SOLAR NETWORK CHARGING STATION FOR ELECTRIC VEHICLES WITH A CAPACITY OF 30 KW

Scientific Advisor– DSc (Engineering), Prof. Hnatov A.V.
Language Advisor – DSc (Education), Prof. Saienko N.V.

Introduction

With the increasing demand for electricity and the disadvantages associated with fossil fuels, there is a growing interest in renewable energy sources that compete with traditional sources. Solar photovoltaic energy is becoming increasingly popular in many areas of application, as it can significantly reduce greenhouse gas emissions, costs associated with the use of electricity in the power grids of distribution system operators, and reduces the load on the power grid (Nkuriyingoma, 2019).

The state support policy over the past 10 years has made it possible to launch the photovoltaic industry in Ukraine and reach large volumes in terms of total installed capacity. Thus, at the beginning of 2021, almost 7 GW of solar power plants were installed throughout Ukraine.

Calculation of electricity generation by a grid-tied solar charging station

The potential of solar energy in Ukraine is high enough for the widespread introduction of photovoltaic equipment almost throughout the country. Over 70% of the annual amount of solar energy reaches the surface during the 6-month thermal period of the year (Tytko, & Kalinichenko, 2010).

The design of a solar charging station begins with determining the position of solar panels on the installation site. In this study, we propose a stationary installation of solar panels with a single tilt angle and azimuth angle for all PV modules. The advantages of this method are relatively cheap installation costs, ease of maintenance, and low energy losses.

The period from April to September has the highest level of solar insolation, which means that we will be able to get the maximum electricity generation during this period. The solar panels are mounted with the solar panels facing south (azimuth angle is 0°); to determine the optimal tilt angle during the warm season, we subtract 15° from the latitude value. We select the determined data of the tilt and azimuth angle in the BlueSol Design software environment (Fig. 1).

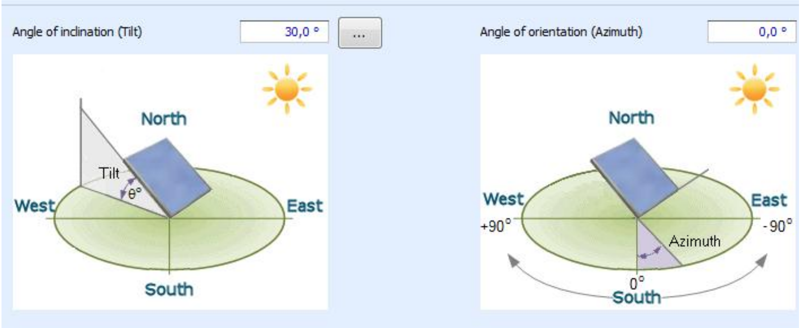

Fig. 1 – Azimuth and tilt angle of the solar module in the BlueSol software environment

The 203 m^2 PV system consists of 94 solar panels and one three-phase inverter, as shown in Fig. 2, uses a series-parallel configuration and will be divided into 2 rows of 24 modules and 2 rows of 23 modules each, connected in series. Table 1 shows the characteristics of the selected PV panels and inverter.

The PV system will be connected to a 400 V low voltage three-phase AC grid, which is the responsibility of the grid operator. The rated power of the photovoltaic system $P_{nom,s}$ is defined as the sum of the rated powers of each module measured under standard test conditions (STC) with an excess of 10% with a safety factor, kW.

The calculation of the energy produced by the system takes into account the rated power, tilt angle and azimuth of the solar module, and the losses of the photovoltaic system (resistive losses, losses due to temperature differences between the modules).

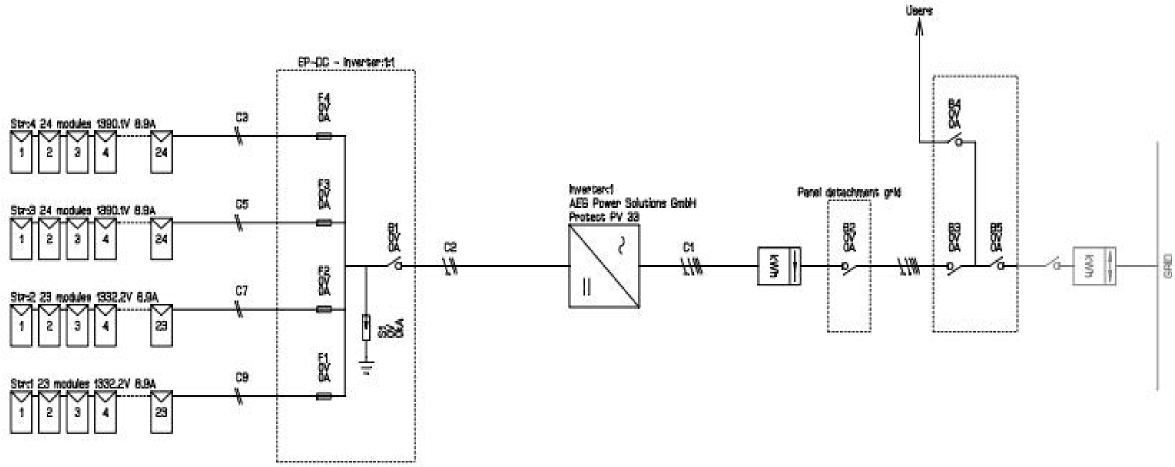

Fig. 2 – Schematic diagram of the photovoltaic charging station

Table 1 - Characteristics of photovoltaic panels and inverter

Photovoltaic panel		Inverter	
Producer	1 Soltech Inc.	Producer	AEG Power Solutions GmbH
Model	1 STH-350	Model	Protect PV 33
Technology	Si-Mono	DC Input Power	34.6 kW
Nominal power	350 W	AC Output Power	33 kW
Tolerance	3%	Min MPPT Voltage	300 V
No-load voltage (Voc)	51.5 V	Max MPPT Voltage	800 V
Voltage at max. power Vmpp	43 V	Max current from PV	13 A
Short circuit current (Isc)	8.93 A	Max voltage from PV	800 V

Current at max. power (Impp)	8.13 A	Connection type	Three-phase
Area	2.16 m^2	Frequency	50/60 Hz
Efficiency	16.2%	Efficiency	97%

Fig. 3 shows the trend of monthly energy production expected during the year.

Fig. 3 – Monthly production volume expected during the year

Conclusions

This paper investigates the development of a 30 kW grid-tied solar charging station for electric vehicles. In the course of the study, the following results were obtained:

- the analysis of literature journals was carried out and the issue of the possibility of charging electric vehicles using photovoltaic energy was considered;

• the development and calculation of the power generation of a 30 kW grid-tied solar charging station for electric vehicles was carried out. During the year of operation, the developed solar charging station is capable of generating 38.68 MWh;

• the use of the proposed configuration of a grid-tied solar charging station for electric vehicles will reduce CO2 emissions from the generation of electricity to 28.8 tons per year.

The results of the work should be used in the design of modern green, renewable sources of electricity and solar charging stations for electric vehicles.

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Shpeniovych V. V., Shpeniovych A. V.

IMPROVING THE QUALITY OF WELDED JOINTS FROM ALUMINUM-MAGNESIUM ALLOYS WHEN WELDING IN INERT GASES

Language Advisor – Asst. Prof. Vorobyova S. V.

The purpose of the work: To conduct a study of the influence of mixtures of shielding gases on the technological characteristics and quality of welded joints of aluminum-magnesium alloys.

Object of research: Welded joints of aluminum alloys made in a mixture of shielding gases.

The subject of the study: The influence of the composition of the mixture of shielding gases on the technological characteristics and quality of welded joints of aluminum alloys.

Objectives of the study:

1. Based on the conducted literature review, develop a research methodology.

2. To conduct a study of the effect of the mixture of argon-helium-neon gases on the parameters of the I-V characteristics.

3. To conduct a study of the introduction of neon into the mixture of inert gases on the geometric parameters and the quality of the seams of welded joints.

Technological properties of deformable aluminum alloys

Name	Technological properties by brands						
	АД1	АМц	АМг	АД	АВ	1925	1915
Plasticity:							
in an annealing state	High	High	High	High	High		
in semi-annealed condition	average						
Machinability by cutting:							
in an annealing state	Unsatisfactory						
in semi-annealed condition	-	-	Satisfactory	-	-	-	-
Weldability	good		****	****	****	****	****
Type of welding	All types		All types	****	****	****	****

Fig. 1. Technological properties of deformable aluminum alloys

Composition of aluminum alloy welding wires (DSTU 7871)

Brand	Percentage by mass							Others, no more than % by mass
	Mg	Mn	Fe	Si	Ti	Be	Zr	
СвАМг3	3,2... 3,8	0,3... 0,6	-	0,5... 0,8	-	0,002... 0,005	-	0,85
СвАМг4	4,0... 4,8	0,5... 0,8	-	0,05... 0,25	0,05... 0,15	0,002... 0,005	-	1,15
СвАМг5	4,8... 5,8	0,5... 0,8	-		0,05... 0,2	0,002... 0,005	-	1,4
Св1557	4,5... 5,5	0,2... 0,6	0,07... 0,15			0,002... 0,005	0,2... 0,35	0,6
СвАМг6	5,8... 6,8	0,5... 0,8	-			0,002... 0,005	-	1,20
СвАМг63	5,8... 6,8	0,5... 0,8	-			0,002... 0,005	0,15... 0,35	1,15
СвАМг61	5,5... 6,5	0,8... 1,1	-			0,0001. 0,0003	0,002... 0,12	1,15

Fig. 2. Composition of aluminum alloy welding wires (DSTU 7871)

The influence of the composition of the shielding gas on the range of average temperatures of the metal of the electrode drops (a) and the magnesium content in them (b) (welding with SvAMg5 wire, del=2.5 mm, Izv=400 A) [1] (Fig. 3).

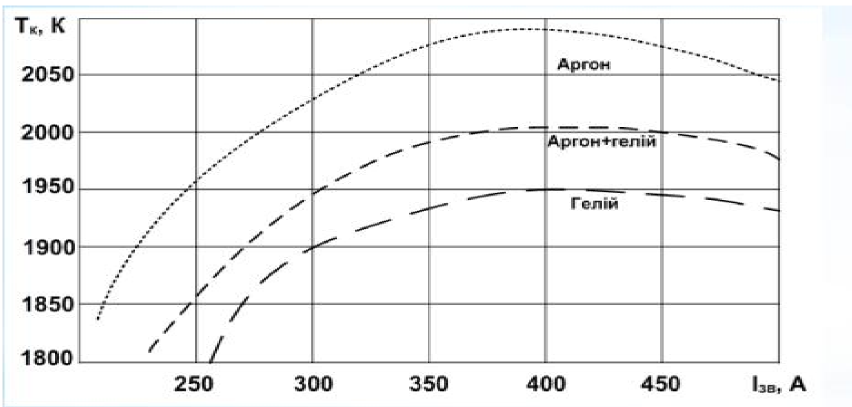


Fig. 3. Effect of welding current and gas composition on the average droplet temperature

Analysis of BAX of a pulsed arc burning in argon, neon, helium and a helium-neon mixture (15% neon) at different feed speeds of the electrode wire (at arc length Ld = 2...18 mm) showed that with the same welding current, the voltage on the arc burning in neon is 4...8 V higher than in argon [1] (Fig. 4-5).

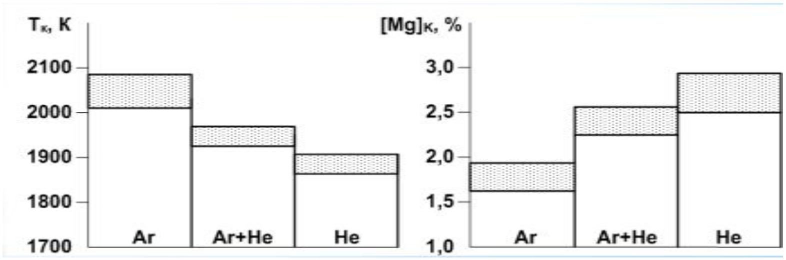


Fig. 4. Volt-ampere characteristics of an arc burning in neon (solid curve) and argon (dashed curve) with a pulsed arc

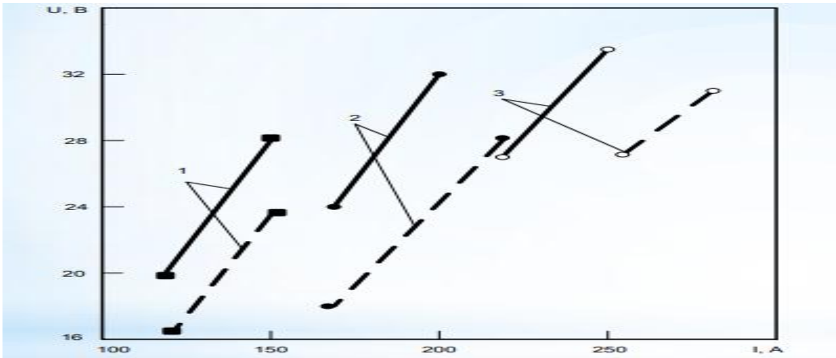
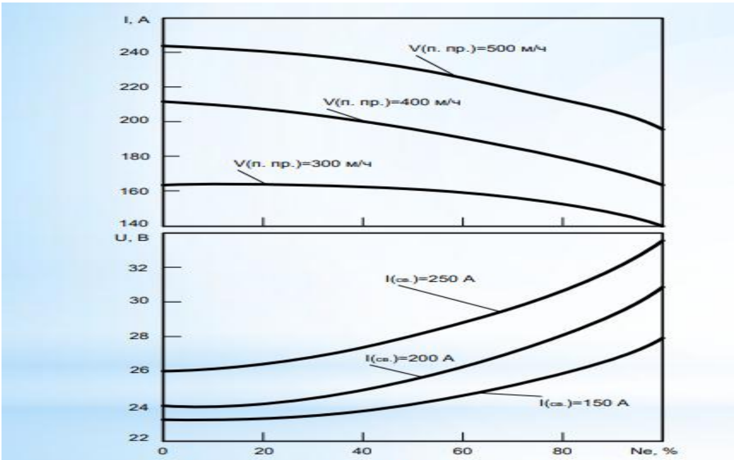


Fig. 5. 1- wire feed speed 300 m/h; 2 – wire feed speed 400 m/h; 3 - wire feed speed 500 m/h

At the same wire feeding speeds, the arc voltage in the helium-neon mixture is 0.5...1.5 V lower than in helium alone. The higher the average value of the welding current, the smaller the difference in values between the arc burning in helium and the helium-neon mixture. The introduction of neon into argon up to 100% (at Vp.dr = const) leads to a shortening of the arc length, an increase in spattering of the electrode metal, and a decrease of 20...30 A in the average welding current (a). To restore the stability of the welding process and the current, it is necessary to increase the arc voltage by 2...8 V, depending on the content of neon in the mixture and the amount of current (b). At the same time, the depth of metal penetration and the width of the seam increase by 0.7...1.1 and 1.9...2.3 mm, respectively. To the greatest extent, the influence of neon on the electrical parameters of the arc and the geometric shape of the seams is manifested when its content in the mixture exceeds 40% (Fig. 6).



a - constant supply of welding wire;
b - constant welding current

Fig. 6. Effect of neon in argon-neon mixture on welding current at UD=25 V (a) and arc voltage (b), pulsed arc

As with the pulsed arc, the replacement of argon with neon (He = 0%) leads to an increase in the depth of penetration, the width of the seam and a decrease in its bulges. The introduction of helium into neon (at constant values of Izv) contributes to the further growth of the depth and width of the seam, especially with an increase in the content of helium from 30 to 65% [2] (Fig. 7).

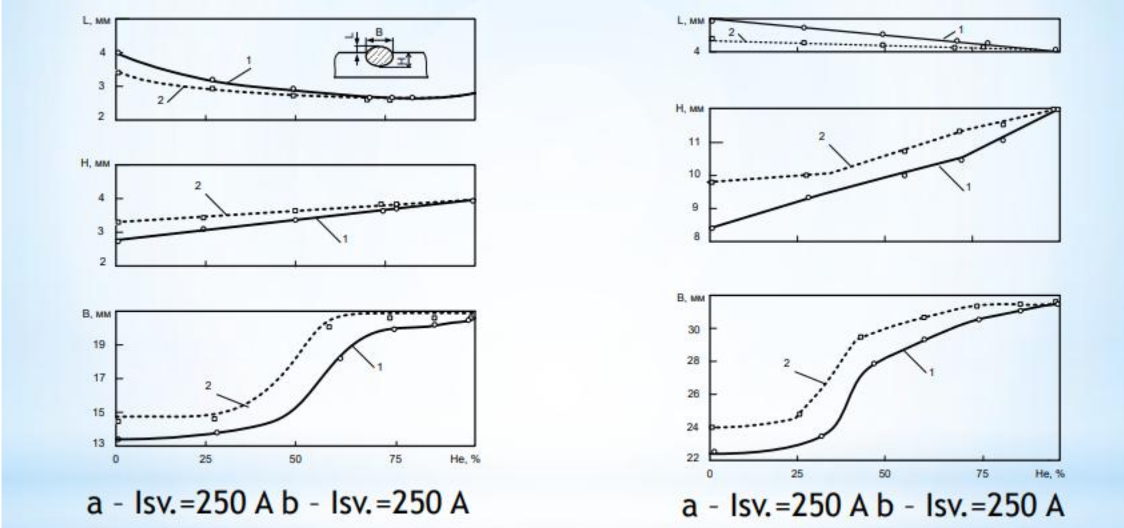


Fig. 7. The effect of the composition of the helium-argon (1) and heliumneon (2) mixture on the geometric parameters of the seams obtained by ZPE (ddr=2.0 mm, LD=4±1 mm; Vzv.=20 m/g)

Thus, at any ratios of neon and helium, regardless of the method and modes of welding, the width and depth of penetration of the base metal is greater than at the same ratios of argon and helium. The geometric parameters of seams made in helium and helium-neon mixtures (He > >85%; /св = 250...350 A; Vzv= 15...20 m/g) have practically the same values (Fig. 8). In the case of using a mixture of gases with a content of more than 92...95% of helium, neon impurities do not affect the size of the seams.

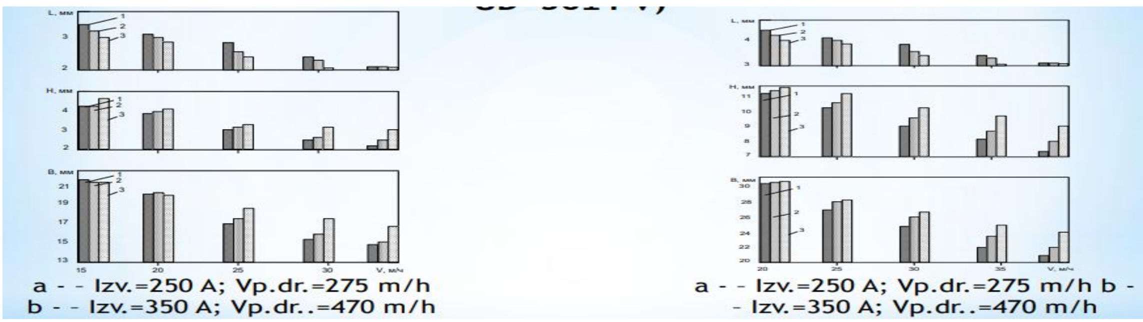


Fig. 8. Influence of the speed and composition of the shielding gas (1 – helium; 2 – helium (base) + 15% neon; 3 – helium (base) + 15% argon) on the geometric parameters of the seams at ZPE (ddr=2.0 mm; UD=36±1 V)

The change in the shape of the seam depending on the type of shielding gas can be seen on the presented macro sections. The minimum volume of the welding bath is typical for welding in argon, the maximum is in helium. The volume of the bath and the geometric characteristics of the seam when welding in neon occupy an intermediate place between them (Fig. 9).

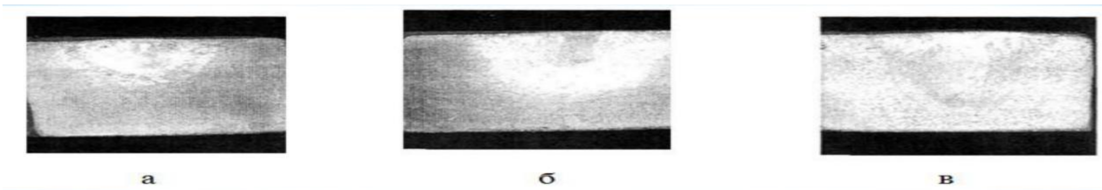


Fig. 9. The influence of the composition of the protective medium on the formation of a seam during welding with direct polarity current (x3.5): a – welding in argon; b – welding in neon; c – welding in helium

The quality of the seam surface in terms of appearance changes little when neon is added to the protective mixture. Both in argon and when using neon, the surface of the seam is clean, without any plaque or foreign inclusions. The use of neon with a higher ionization potential leads to a violation of the stable burning of the arc during the transition of pulses into half-cycles of reverse polarity. Macro sections of the samples give a visual representation of the formation of seams during welding on alternating current (Fig. 10).

Fig. 10. Influence of the composition of the protective medium on the formation of the seam during welding with alternating current ID=190 A; LD=4 mm (x2, reduced by 1/2): a – welding in argon; b - welding in neon

Conclusions. Studies have shown:

1. Porosity in deposited metal obtained in neon and helium-neon mixtures is 1.1...1.6 times less than in argon and helium-argon mixtures. This is related to the thermophysical properties of neon and its lower content of "harmful" impurities (hydrogen, moisture, hydrocarbons, etc.) compared to argon.

2. In connection with the increase in the volume (mass) of the welding bath during welding in neon, it can be assumed that neon, like helium, lowers the average temperature of the electrode metal drops and increases the average temperature of the welding bath. This creates more favorable conditions for reducing the solubility of hydrogen in electrode drops and increasing the rate of its release from the welding bath in the form of gas bubbles.

3. The use of ternary mixtures of inert gases, prepared on helium-neon mixtures supplied in cylinders, and argon (50...70% Ne + 3...23% Ne + 7...47% Ar), allows additionally reduce the cost of shielding gas and, accordingly, reduce the cost of welding work [3]. Replacing helium-argon mixtures with ready-made helium-neon mixtures when welding aluminum alloys leads to an increase in arc voltage, an increase in the depth of penetration of the metal, an increase in the

width of the seam, a decrease in its convexity and a decrease in porosity in the deposited metal.

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Stryzhak H.O.

TRACING THE DEVELOPMENT OF THE INTERNAL COMBUSTION ENGINE

Language Advisor – Senior Lecturer Ivanova I.L.

The internal combustion engine (ICE) is one of the key inventions that changed the world, especially in transportation, industry and energy. Its development has spanned several centuries and is attributed to the efforts of inventors, engineers and scientists.

The idea of using combustible materials to produce energy has existed since antiquity. The Chinese and Greeks experimented with gunpowder engines, but these were likely disposable mechanisms similar to fireworks. The breakthrough came during the Industrial Revolution, when there was a need for more compact and powerful power sources. Steam engines, such as those developed by Thomas Newcomen and James Watt, dominated the era. While steam engines were revolutionary, their disadvantages—such as bulkiness and low efficiency—stimulated the search for an alternative solution, leading to the development of the internal combustion engine.

The first working internal combustion engine was created by Étienne Lenoir in 1860, running on luminous gas. Despite its low efficiency, Lenoir's engine became relatively popular and was used in motorboats. In the fall of 1860, the German designer Nikolaus August Otto, along with his brother, built a copy of Lenoir's gas engine. In January 1861, they applied for a patent for a liquid-fuel engine based on Lenoir's design to the Prussian Ministry of Commerce, but the application was rejected. In 1863, Otto developed a two-stroke atmospheric internal combustion engine. This engine featured a vertical cylinder arrangement, open-flame ignition, and an efficiency of up to 15%, eventually surpassing the Lenoir engine in performance.

However, the engine operated on an imperfect four-stroke cycle—it lacked pre-compression of the fuel-air mixture, which significantly reduced its power. The idea of compressing the mixture was proposed by the French engineer Alphonse Eugène Beau de Rochas, who developed the theoretical principles of four-stroke internal combustion engine operation. The most critical of these principles was the compression of the working mixture before ignition. Beau de Rochas emphasized the previously underestimated importance of this step, publishing his findings in 1861—16 years before Nikolaus August Otto received his patent. Beau de Rochas elaborated on these ideas in his book "Newest Investigations Concerning the Practical Conditions for the Application of Heat" published in Paris in 1863.

The next step in the development of internal combustion engines was the patent application filed by Rudolf Diesel on February 27, 1892. He applied for a patent for a “new rational heat engine,” which was granted by the Imperial Patent Office in Berlin on February 23, 1893, under the title “Method and Apparatus for Converting High Temperature into Work.” A second patent, incorporating a modified Carnot cycle, was registered on November 29, 1893.

From 1893, the development of a new engine was underway at the Augsburg Machine Works (renamed M.A.N. in 1904). The first functional engine was built by Rudolf Diesel there in 1897. This engine had a power output of 20 horsepower at 172 rpm, an efficiency of 26.2%, and a weight of five tons. It was far superior to Otto's existing engines, which had an efficiency of 20%, and marine steam turbines, which had an efficiency of only 12%. This significant improvement attracted immediate interest from various industries. Diesel's engine quickly found applications and was highly valued in many countries. However, in his homeland, Rudolf Diesel did not receive the recognition he deserved, which caused him great personal distress.

Diesel's engine was a four-stroke engine. The inventor discovered that the efficiency of an internal combustion engine could be increased by raising the compression ratio of the mixture. However, compressing the combustible mixture too much caused the pressure and temperature to rise, leading to premature spontaneous ignition. To solve this problem, Diesel decided to compress pure air instead of the combustible mixture. Towards the end of the air compression phase, liquid fuel was gradually injected into the cylinder under high pressure. As the temperature of the compressed air reached 600–650 °C, the fuel spontaneously ignited, causing the gases to expand and move the piston. This innovation allowed Diesel to significantly improve the engine's efficiency. Additionally, the engine no longer required an ignition system, as the spontaneous ignition eliminated the need for spark plugs. Instead of a carburetor, a fuel pump delivered the fuel to the cylinder.

In the 20th century, due to wars and the rapid progress of aviation, piston engines of existing designs struggled to meet the demanding working conditions. As a result, engineers began exploring new types of power plants. These included jet engines, turbojet engines, and rotary internal combustion engines.

Jet engines generate the thrust necessary for motion by converting the internal energy of fuel into the kinetic energy of a jet stream. While they began to emerge before World War II, their major development occurred during the space race. Wernher von Braun made an invaluable contribution to this field; the engines he developed for the Saturn V rockets enabled the successful execution of the lunar program. Without the development of such powerful and reliable propulsion systems, achieving escape velocity and traveling beyond Earth’s atmosphere would have been impossible.

The development of the closed-cycle turbojet engine, which converts thermal energy into rotational energy of the turbine shaft and compressor, began on January 16, 1930. On this date, Frank Whittle registered the world's first patent for a workable turbojet engine (UK Patent No. 347206). In 1936, Whittle and his colleagues established a company, Power Jets Ltd., which developed the first

British turbojet engines. Although Frank Whittle was the first to obtain a patent for a workable turbojet engine, Hans-Joachim Pabst von Ohain surpassed him in the practical application of the design. marking the true beginning of practical jet aviation.

The rotary internal combustion engine, first demonstrated by Felix Wankel in 1957, was once envisioned as a full-fledged replacement for the piston engine. However, despite the best efforts of NSU, Mazda, and subsequent designers, they were unable to meet the increasingly strict environmental standards. Additionally, the durability of these engines remained an issue, along with the relatively high cost of manufacture and repair. As a result, by the present time, such engines have nearly disappeared, and their areas of application have been largely taken over by piston engines, hybrids, and gas turbines.

In conclusion, the internal combustion engine has played a transformative role in shaping modern society, revolutionizing transportation, industry, and energy production. From early experimentation with combustible materials to the breakthroughs of inventors like Lenoir, Otto, Beau de Rochas, and Diesel, the development of the internal combustion engine has been a remarkable journey of innovation. Diesel's advancements in efficiency, combined with the evolution of jet engines and rotary engines, exemplify how engineering ingenuity has continually pushed the boundaries of what is possible.

Although alternative power sources, such as electric engines and fuel cells, are emerging as contenders for the future of transportation and energy, the internal combustion engine remains a cornerstone of industrial progress. The pursuit of higher efficiency, reduced emissions, and sustainability continues to drive improvements in engine technology. As we move forward into an era of clean energy and environmental responsibility, the legacy of the internal combustion engine will undoubtedly influence the ongoing development of new, more sustainable technologies. Its history underscores the profound impact of innovation and the continuous quest to meet the needs of an ever-evolving world.

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Sumchenko O. V.

INCREASING THE DURABILITY OF MINING EQUIPMENT COMPONENTS

Language Advisor – DSc (Education), Prof. Saienko N.V.

Mining equipment operates under extreme conditions such as high loads, abrasive wear, exposure to aggressive environments, high humidity, and cyclic and impact loads. To enhance the durability of mining equipment components, various approaches can be considered, categorized as follows:

Materials and coatings presuppose the use of high-strength and wear-resistant materials, particularly steels with high hardness, as well as unconventional combinations of different steels and non-metallic materials. The application of protective coatings, such as hard alloys, ceramic coatings, and polymer materials, improves wear resistance and hardness. Non-standard thermal treatment methods are applied to enhance the mechanical properties of steels.

Structural Solutions. Optimizing equipment designs are used to reduce loads on critical components of mining machinery. Using replaceable and combined components minimizes wear on expensive parts.

Improvement of Lubricants and Tribological Properties. Special lubricants resistant to high temperatures and specific pressures are employed. Technologies for self-lubricating materials, including additional coating properties, are also utilized.

Surface Hardening Methods. Laser or plasma hardening strengthens the surface. Layered structures are applied using cladding or chemical-thermal treatment methods such as carburizing and nitriding.

Improvement of Operating Conditions. Regular maintenance and monitoring of equipment conditions are essential. Aggressive environmental impacts are mitigated using sealing or ventilation.

Innovative Technologies. Nanomaterials and composites are introduced. 3D printing is used to manufacture complex geometries with high precision.

Monitoring and Diagnostics. Sensors are installed to monitor wear, temperature, and vibration of components. Machine learning technologies predict failures.

From a materials science perspective, particular interest lies in materials and coatings, improving tribological properties, and surface hardening methods.

Based on five years of practical experience in mining equipment engineering, energy-efficient heat treatment [1] of low-alloy weldable steels such as 9MnSi5, as well as unconventional combinations with difficult-to-weld steels like 40X or Steel 45, is a key area of interest.

This focus includes four main directions: 1) heat treatment to improve the mechanical properties of 9MnSi5 steel; 2) technological aspects of heat treatment for low-alloy steels; 3) thermal or chemical saturation of steel surface layers with various chemical elements; 4) internal metal mechanics for stress relief in dissimilar steels.

Heating steel above the critical point Ac3 (typically 900–950°C) followed by air cooling improves structural homogeneity, reduces internal stresses, and increases impact toughness. This treatment results in a pearlitic structure, which provides limited durability improvement, except for machine parts under high cyclic or peak loads.

Rapid cooling after heating to 860–880°C (quenching) forms a martensitic structure, significantly enhancing steel strength. However, this structure requires subsequent tempering to refine martensite, decompose retained austenite, relieve stresses, and reduce brittleness while increasing plasticity. Isothermal tempering with controlled cooling rates and temperature intervals produces a bainitic structure, offering a unique combination of strength, hardness, and plasticity. This makes it suitable for enhancing the durability of mining machinery components and underground transportation.

The alloying elements manganese (Mn) and silicon (Si) in 9MnSi5 steel influence phase transformation kinetics, supporting the formation of a fine, strong bainitic structure. Manganese delays austenite transformation, facilitating a finer bainitic structure, while silicon prevents cementite formation, promoting upper bainite with a ferritic matrix.

The prerequisites for achieving such a structure in 9MnSi5 steel are the alloying elements manganese (Mn) and silicon (Si), which influence the kinetics of phase transformations. Manganese slows down the transformation of austenite, promoting the formation of a finer and stronger bainitic structure. Silicon prevents the formation of cementite, facilitating the development of upper bainite with a ferritic matrix.

Lower bainite forms at low temperatures (250–350°C) and is characterized by thin ferrite plates with dispersed carbide particles. This type possesses high hardness and strength. Upper bainite forms at higher temperatures (350–550 °C) and consists of ferrite plates with carbides located in the interplate space. It has lower hardness but better plasticity. In some design solutions, achieving durability may even favor the properties of upper bainite.

Task for heat treatment. Achieving a uniform fine-grained microstructure without macrostructural defects is essential. Studies comparing steels with pearlitic, bainitic, martensitic, and austenitic structures [2] concluded that bainitic steels with fine carbide dispersion and high dislocation density are most advantageous. Martensite formation is undesirable due to residual stresses, which may cause micro-spalling and cracking.

To balance martensite's properties, surface layers can be carbon-saturated with subsequent quenching. Alloying elements such as manganese and silicon enhance carburizing kinetics. Manganese increases the hardness and strength of the carburized layer, while silicon improves wear resistance.

Proposed methods for enhancing the durability of a traction sheave. The traction sheave of a mining railway system endures constant friction loads due to interaction with steel cables. Two methods are proposed:

Isothermal quenching for lower bainitic structure. The sheave and companion samples with similar cross-sections will undergo quenching in water and oil to slow the initial cooling rate, fixing cooling at 250°C. Temperature equalization across the section will follow, with furnace cooling to room temperature. Metallography, tensile strength, and impact toughness tests will assess changes in parameters based on cooling rate and isothermal holding temperature.

Carburizing the sheave's groove. Carburizing will achieve a depth of 0.8–1 mm using 3–5 mm fraction charcoal as the carburizer, combined with a catalyst – barium soda. Investigations will vary carburizing temperature, depth, and the carburizer-to-sheave mass ratio.

Practical durability tests of the two sheaves in mining conditions will be conducted at "Pavlogradugol" production facilities.

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Tsyhanok Y. O.

SOLAR PANELS

Language Advisor – DSc (Education), Prof. Saienko N. V.

The transition to renewable energy has become a global trend due to increased attention to ecology and energy efficiency. One of the leading technologies in this area is solar panels. They convert sunlight into electricity, ensuring autonomous and eco-friendly energy supply.

A solar panel, also known as a photovoltaic converter, consists of a set of photovoltaic cells made from semiconductor materials, usually silicon. The basic principle behind their operation is the photoelectric effect, discovered by Alexandre Becquerel in the 19th century. This effect occurs due to the movement of electrons between layers with different conductivity:

- n-layer: a layer with an excess of electrons (cathode);
- p-layer: a layer lacking electrons (anode).

When sunlight hits the n-layer, the energy of photons "knocks out" electrons, forcing them to move to the p-layer. This process generates a current that is then transferred to an electrical circuit. One significant advantage of solar panels is the absence of chemical reactions, which ensures their long service life.

To increase the efficiency of photovoltaic cells, scientists are experimenting with adding materials such as gallium arsenide, copper, and indium. These technologies help improve the energy conversion rate (efficiency), which currently rarely exceeds 25%.

Several main types of solar panels are available on the market today, differing in efficiency, cost, and application:

1. Monocrystalline Panels:

- made from a single silicon crystal;
- high efficiency (15–20%), with some models reaching 21.3%;
- ideal for small areas with high energy demand.

2. Polycrystalline Panels:

- made from multiple silicon crystals;
- slightly lower efficiency (13–16%) but much more affordable;
- characterized by a distinctive blue sheen.

3. Thin-Film Panels:

- lightweight and flexible, made by applying a photosensitive layer onto glass or plastic;
- efficiency of 10–12%, offset by low cost and versatile applications.

4. Cadmium Telluride (CdTe) Panels:

- utilize thin-film technology and are less harmful to the environment during production;
- efficiency reaches 11–12%.

5. CIGS Panels:

- made from a mixture of indium, gallium, copper, and selenium;
- efficiency ranges from 10–15%;
- a promising technology that is rapidly developing but still occupies a small market share.

The use of solar panels offers several significant benefits:

- renewable energy source: sunlight is available wherever there is direct access to the sky;
- cost reduction: while initial installation requires investment, it reduces electricity bills in the long run, and excess energy can be sold;

- autonomy: especially important for remote areas where connection to the central grid is challenging;
- eco-friendliness: the absence of harmful emissions and long lifespan make solar panels safe for the environment.

Despite their advantages, solar panels have some limitations:

- dependence on climate: in regions with few sunny days, panel efficiency decreases;
- heating issues: excessive heat can reduce performance;
- sensitivity to shading: even minor shading can significantly lower energy production.

It is also essential to consider installation location, sunlight availability, and energy requirements. A prior audit is recommended to determine the optimal system configuration.

Today, solar panels are used in a wide range of areas, from household needs to large industrial projects. They are installed on rooftops, integrated into vehicles, and even used to power mobile devices and drones.

The prospects of solar energy are linked to the development of new materials and technologies aimed at improving efficiency and reducing costs. Scientific research focuses on solving issues such as excessive heat and performance reduction in hot climates.

Additionally, solar panels are expected to become more integrated into daily life, from smartphones to transportation systems. This shift will help reduce dependence on traditional energy sources and bring humanity closer to a sustainable future.

Solar panels are an effective and eco-friendly solution for modern energy needs. They provide autonomy, reduce costs, and contribute to environmental conservation. With continuous technological advancements, solar panels are becoming more accessible and efficient, opening new horizons for energy savings and innovation.

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Volianska N. V.

SLIDING MODE CONTROL OF INTERVAL LINEAR DYNAMIC OBJECT

Scientific Advisor – Prof. Shubin I.
Language Advisor – DSc (Education), Prof. Saienko N.V.

Introduction

The parameters of some technical objects and industrial processes can varied in wide ranges. This fact doesn't allow to use many of known control strategies without their adaptation to variations of parameters of the controlled object. One of such strategies is feedback control based on feedback transformation method (Seoa, 2007). This method is very sensitive for variations of right-hand sides equations of motion. So in scientific literature there are many publications devoted to feedback transformation with some uncertainty based on methods of theory robust control (Rehman, 2009), methods of neural net (Shouling, 2002) and so on. These publications solve very important problem, but they have some limitations.

In our paper we will show a feedback transformation for linear dynamic object based on the usage of interval methods. Although our results can be used for nonlinear objects too.

Feedback linearization of interval dynamic object

Let us consider a single input single output (SISO) dynamic object:

$$px_j = \sum_{i=1}^{n} a_{ij}x_i + m_n U; y = x_1, \ j \in [1, n], \tag{1}$$

where parameters a_{ij} and m_n can varied in known ranges, p – Laplace's operator, x_i – state variables, U – control signal, y – output signal, n – order of the dynamic object.

We replace the variable parameters with appropriate interval variables:

$$\tilde{a}_{ij} = [a_{ij_{min}}, a_{ij_{max}}], \tilde{m}_n = [m_{n_{min}}, m_{n_{max}}] \tag{2}$$

and let us rewrite the equation (1) in such way:

$$p\tilde{x}_j = \sum_{i=1}^{n} \tilde{a}_{ij}\tilde{x}_i + \tilde{m}_n\tilde{U}; \ y = x_1, \ j \in [1, n]. \tag{3}$$

Transition from the equations (1) to (3) allows us to consider the interval dynamic object. In contrast to the object (1), equations (3) describe not one trajectory in phase plane, but family of theirs.

Let us transform equations (3) to the canonical form:

$$
\begin{aligned}
&p\tilde{y}_j = \tilde{y}_{j+1};\ j \in [1, n-1],\\
&p\tilde{y}_n = -\sum_{i=1}^{n} \tilde{b}_i \tilde{y}_i + \tilde{M}_n \tilde{U}\ ,
\end{aligned}
\qquad (4)
$$

where $\tilde{b}_i$ – eigenvector's coefficents of matrix $\tilde{A} = \left\| \tilde{a}_{ij} \right\|$ and $\tilde{M}_n$ defined as follows:

$$
\tilde{M}_n = \tilde{m}_n \prod_{i=1}^{n} \tilde{a}_{i,i+1}\,. \qquad (5)
$$

It's clear that coefficients $\tilde{M}_n$ and $\tilde{b}_i$ have interval values, and equation (4) describes an interval object.

With the well known feedback linearization by output (Vidyasagar, 1993) let us rewrite equation (4) to Brunovsky form:

$$
\begin{aligned}
&pz_i = z_{i+1},\ i \in (1, n-1);\\
&pz_n = v,
\end{aligned}
\qquad (6)
$$

where $z_1 = y_1$.

The "old" control signal U is defined by the "new" one as follows:

$$
\tilde{U} = \frac{v}{\tilde{M}_n} + \sum_{i=1}^{n} \frac{\tilde{b}_i}{\tilde{M}_n} \tilde{y}_i \qquad (7)
$$

Since the coefficients $\tilde{M}_n$ and $\tilde{b}_i$ and state variables $\tilde{y}_i$ are interval, control signal $\tilde{U}$ will be interval too. So we must transform it from interval values to exact one.

Let us determine boundary values of control signal U:

$$
\begin{aligned}
&\tilde{U}_{max} = \frac{v}{\tilde{M}_{n_{min}}} + \sum_{i=1}^{n} \frac{\tilde{b}_{i_{max}}}{\tilde{M}_{n_{min}}} \tilde{y}_{i_{max}};\\
&\tilde{U}_{max} = \frac{v}{\tilde{M}_{n_{\max}}} + \sum_{i=1}^{n} \frac{\tilde{b}_{i_{\min}}}{\tilde{M}_{n_{\max}}} \tilde{y}_{i_{\min}}.
\end{aligned}
\qquad (8)
$$

Now we can define control algorithms as follows:

$$U = \begin{cases} U_{max} & if \quad v / p < y_n; \\ U_{min} & if \quad v / p > y_n. \end{cases} \qquad (9)$$

By using the control algorithm (9) we compensate parameters variation in a sliding mode.

Now we can consider dynamic object (4) as the object with stationary parameters and we can use any of classical control strategies and algorithms.

For example, we can define the "new" control signal v by solving modal control problem (Porter, 1972):

$$v = \sum_{i=1}^{n} k_i \left(y_i^* - y_i \right), \qquad (10)$$

where y_i^* – given values of state variables, k_i – coefficient of given characteristic polynomial.

Conclusion

Using the above equations and expressions, we can make the following conclusions:

• boundary values of the control signal U are variable;

• sliding mode control allows us to compensate parameters variations of a dynamic object;

• the order of the used sliding mode is greater than one.

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Zikratyi R. Y.

CARS OF THE FUTURE

Language Advisor- Asst.prof. Vorobyova S.V

Cars of the Future: Technologies

Each year, new technologies emerge that radically improve vehicles. What changes can we expect in future cars? To answer this question, let's explore the latest innovations from leading automakers.

Eco-Friendly and Smart Vehicles

In the near future, passenger cars will become more eco-friendly, practical, convenient, and compact. Flying cars remain within the realm of science fiction, but artificial intelligence, approaching its ideal, will undoubtedly find a place in the market.

Cybertruck by Tesla

An example is the Tesla Cybertruck, an electric vehicle capable of towing over 6,350 kilograms—comparable to the weight of an average African elephant. This is a powerful and reliable vehicle designed to handle tough conditions, resembling something straight out of a "Mad Max" scenario.

BMW iX Flow

The BMW iX Flow can change the color of its body at the push of a button. Its Heads-Up Display (HUD) systems project information onto the windshield, keeping the driver focused on the road without needing to look at screens.

Hyundai Elevate

The Hyundai Elevate showcases impressive off-road capabilities, capable of moving on wheels or walking on four “legs” that lock to prevent rolling back. This innovative vehicle could help wheelchair users overcome stairs where ramps are unavailable.

Energy Efficiency in Future Cars

Modern engines consume significantly less fuel than they did five years ago. Scientists aim to minimize emissions, benefiting the environment. Future cars will feature innovative technical solutions and electronic programs to utilize natural fuels and reduce energy needs.

Some automakers have pledged to phase out traditional engines by 2050. In Japan, experts predict that full independence from oil could be achieved by 2060. Cars of the future will be environmentally friendly, aligning with an increasingly important trend in the automotive industry.

Safety in Future Cars

Future cars will likely come equipped with autopilots, preventing up to 90% of road accidents. With intelligent systems, vehicle interiors will change—

mechanical components will give way to electronics, enhancing safety. Drivers will only need to input destination details, and the car will handle the rest.

Compact Design of Future Cars

Compactness will be a priority in the development of future vehicles. Cars might become smaller than today's models, offering transformation capabilities. However, some believe they could grow larger to provide maximum comfort for drivers and passengers. Future cars will adapt to different situations, and sports models may offer a choice between manual and automatic driving.

Top 10 Technologies of Future Cars

Technological progress is unstoppable. Even today, humanity uses innovations that seemed impossible half a century ago. In the future, renting a car that can park itself might become commonplace. Here are the top 10 features likely to define future cars:

1. Vehicle-to-Vehicle Communication
Advancements in IT and communication will soon enable cars to gather information from other vehicles about road conditions and traffic. A car's onboard computer will analyze this data and alert the driver, reducing accidents and traffic jams.

2. Gesture-Based Controls
Car manufacturers are working on enabling control through 3D gestures. Soon, you may no longer need to touch a screen—just a hand movement will suffice.

3. Smartwatch Integration
Cars are already synchronizing with smartphones, and the next step is integration with smartwatches. This will allow voice commands to control functions like unlocking doors or turning on lights.

4. Parking Integration
Upgraded parking lots with smart software will let cars receive notifications about available spaces, saving drivers time.

5. Self-Parking
Soon, cars may autonomously park in chosen spots using existing sensors and detectors. Imagine summoning your car from a parking lot with a tap on your phone.

6. Full Smartphone Integration
Currently, drivers can partially control cars through their phones. NFC technology will eventually eliminate keys and remotes—just tap your phone to access your vehicle.

7. Lightweight Materials
Innovative materials, such as carbon fiber, will allow future cars to be lighter, making them easier to handle and more efficient.

8. Biometric Scanners
Future vehicles may incorporate fingerprint or facial recognition for unlocking, enhancing security and reducing car theft.

9. Advanced Displays
Traditional displays might be replaced by augmented reality projections on windshields, ensuring drivers can access information without distractions.

10. Side Collision Avoidance
Building on existing safety features for frontal collisions, future systems will also protect against side impacts.

Engines of the Future

Future cars will likely be powered by electricity, with internal combustion engines serving as supplements. One idea involves integrating the Stirling engine, which uses external heat sources to generate mechanical energy, powering hybrid systems. Scientists are also exploring thermoelectric materials to convert heat into electricity, supplementing electric motors.

Autonomous Driving: When Will It Become a Reality?

Major manufacturers are already developing self-driving technologies. Gradual implementation is expected, starting with autonomous parking and eventually allowing cars to drive themselves on dedicated lanes.

By 2030–2040, these zones will expand, supported by infrastructure tailored for such vehicles. Full autonomy is just a matter of time.

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CHEMISTRY, BIOLOGY, PHARMACOLOGY

Alieva T. V.

GOLD REFINING: TECHNOLOGICAL ASPECTS AND MODERN METHODS

Language Advisor – Senior Lecturer Tkachenko S.V

Gold is a chemical element with atomic number 79 and the symbol Au (from the Latin aurum). It belongs to the noble metals and has the following characteristic properties:

- Chemical resistance: gold does not oxidize in air and is resistant to most acids.
- Electrical conductivity: used in electronics due to its low electrical resistance.
- Decorative properties: its natural luster and yellow color make it popular in jewelry.
- Softness and ductility: it can be flattened to the thinnest sheets (gold foil) or stretched into wire with a thickness of only a few microns.

Gold has a symbolic meaning in different cultures, being a symbol of wealth, power and eternity.

Gold refining is one of the key processes in precious metals metallurgy, purifying gold from impurities to the level required for industrial or jewelry use. Various refining technologies are being developed to ensure high purity of the final product and minimize environmental impact. This article provides an overview of modern refining methods, technical schemes and environmental and economic aspects.

Gold mining starts with the primary source of gold, which is ore deposits that are processed by cyanidation. The bulk of gold comes in the form of alloys produced by melting zinc-treated gold precipitates, rough gold after amalgamation, placer gold obtained from the beneficiation of placers and ores, and cathode rough gold from thiourea regenerates. These materials have a complex chemical composition. In addition to gold and silver, they contain copper, lead, mercury, arsenic, antimony, tin, bismuth and other elements as impurities. The content of impurities can reach 200 samples or more. The main chemical reaction involves the dissolution of gold in a solution of sodium cyanide with oxygen to form complex compounds. The next stage is the extraction of gold from the liquid medium by adsorption on activated carbon or precipitation with zinc dust.

The main refining methods are:

1. Electrolytic method

Electrolytic refining, or the Wolvillian method, is the most efficient for achieving high gold purity (99.99%). This method uses an anode made of impure gold that dissolves in the electrolyte, leaving impurities as sludge. The method provides high quality but requires significant energy and equipment (Habashi, 1967).

2. Chemical method

The Miller process is based on the introduction of gaseous chlorine into molten gold. The resulting chlorides of impurities are removed, leaving gold of high purity. This method is cost-effective, but has limitations in terms of achieving purity above 99.5% (911 Metallurgist, n.d.).

3. Solvent extraction (Minataur™)

An innovative technology that involves the extraction of gold with solvents. This method allows to obtain gold with a purity of over 99.999%, having advantages in speed, efficiency and environmental friendliness. The purification process consists of several stages: leaching, extraction, precipitation and smelting (Van Deventer, 1997).

The refining process includes several key stages that differ depending on the method chosen.

For now, let's discuss the solvent extraction method, which in my opinion is the best of all. It includes the following steps:

- Preparation: grinding and enrichment of raw materials.
- Leaching.
- Impurity removal: Chemical or physical processes to purify a solution.
- Precipitation or extraction: The separation of gold from solution.
- Final processing: melting to produce bullion.

Solvent extraction is widely used in various industries for both upgrading and purifying a range of elements and chemicals. The technology is used in applications as diverse as ore processing, pharmaceuticals, agriculture, industrial chemistry, petrochemicals, food processing, base metal refining and precious metal refining. This review addresses the basics of solvent extraction techniques and discusses in detail its applications in several areas, focusing on ore processing and the extraction of important metals from an economic and industrial perspective. (5)

New refining technologies are focused on reducing environmental impact. For example, the use of biotechnology for gold leaching or the use of less toxic solutions reduces the amount of hazardous waste. In addition, closed cycles are being developed to reuse reagents (Marsden & House, 1992).

Modern gold refining methods ensure the production of high-purity metal that meets environmental and economic requirements. The choice of method depends on the characteristics of raw materials and production conditions. Innovations in this area help to improve process efficiency and reduce environmental impact.

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Kulakova A. A.

THE HISTORY OF PSYCHIATRY: DEVELOPMENT OF TREATMENT APPROACHES AT LONDON'S BETHLEM MENTAL

Scientific Advisor – Candidate of Philological Sciences, Assoc. Prof. Yazlovytska O.V.

Language Advisor – Candidate of Philological Sciences, Assoc. Prof. Yazlovytska O.V.

The history of psychiatry is a complex and tragic path of development, reflecting the evolution of public attitudes towards mental illness and its treatment. The first psychiatric hospitals, also known as asylums or institutions for the insane, often treated patients not as people in need of help, but as dangerous or unfit for society. At the time, scientific understanding of mental illness was limited, leading to the use of harsh treatments based on fear and ignorance. Isolation, compulsory therapy and sometimes physical punishment were used as the main approaches that left a deep mark on the psyche of patients and influenced their behaviour (Сонник, Напрєєнко, Скрипніков, 2023).

The study of the history of psychiatry has not only academic value. It opens the door to understanding changes in psychological views, humanism and the impact of medical practices on the lives and minds of patients. This article will look at how early treatments influenced the mental state of patients and explore one of the real historical cases that provides a glimpse into the world of psychiatry of the past. This analysis will also show how important it is to treat patients with understanding and compassion rather than suspicion and fear.

Thus, the history of psychiatry dates back to ancient times, when mental disorders were attributed to supernatural forces. In different cultures, mental illness was often considered to be the result of possession by evil spirits or punishment for sins, and as a result, patients were religiously persecuted and often subjected to physical suffering. For example, in ancient Greece and Rome, demonic influences were believed to be the main cause of mental illness, but later other, more scientific views emerged.

As early as the 4th century BC, the first attempts to explain mental illness in terms of physiology were made. The Greek physician Hippocrates laid the foundation for this approach. Contrary to demonological beliefs, he argued that mental illness, like all other diseases, has physiological causes.

Medieval Europe was dominated by demonological theories that interpreted mental illness as the result of sin or possession. Treatment included exorcisms and physical punishment. At the same time, the Islamic world developed humane treatment practices, such as herbal medicine and relaxation methods in hospitals in Baghdad and Damascus.

With the beginning of the Renaissance in Europe, a more systematic approach to medical institutions emerged. The first specialised psychiatric hospitals, such as the Hospital de los Inocentes in Valencia, founded in 1409, became an important stage in the development of psychiatry. Unlike other institutions, more humane methods of treatment were introduced here. Nevertheless, demonological beliefs continued to influence the treatment of mental patients even into the eighteenth century. In particular, the myth about the influence of the moon on the psyche remained popular, which was reflected in the term ‘sleepwalker’, which was used to describe people with mental disorders.

Starting in the 18th century, the scientific approach began to replace religious explanations, contributing to the humanisation of hospitals and the introduction of treatment programmes focused on understanding the causes of illness. In the nineteenth century, psychiatry developed as a separate discipline, focusing on complex therapy.

The 20th century brings humane and scientific approaches, with the development of psychoanalysis, cognitive and behavioural therapies, and pharmacological drugs. This led to an increase in tolerance and understanding towards people with mental disorders.

As an example, let us note the story of James Tilley Matthews, who was a patient of the Bethlem Hospital in London (known as Bedlam), one of the oldest psychiatric institutions founded in 1247. Conditions in the hospital were harsh and lacked a humane approach to patients. Patients were isolated and subjected to cruel and often inhumane methods of 'treatment', due to the limited medical knowledge of mental illness.

Matthews had vivid illusions about 'mechanical persecution' and 'psychic influence'. He was convinced that his enemies were controlling his mind and inflicting suffering on him through a fictional device he called an 'air loom'. This device, he said, penetrated his thoughts and body, making him feel pain and changing his thinking. The 'air loom', according to Matthews, was equipped with numerous levers, batteries, retorts and cylinders used by mysterious 'agents' he believed to be located near Bedlam.

Matthews' condition was described in detail by John Haslam, a physician at Bethlem Hospital, in 1810. Haslam's detailed notes stood out from general medical practice at the time, as other doctors usually limited descriptions of mental illness to simple terms like 'mad' or 'melancholic'. Haslam sarcastically presented Matthews' illusions as "illustrations of madness," but at the same time, his notes were extremely detailed. Matthews created a detailed engineering diagram of his fictional ‘air loom’ that looked like a scientific blueprint with precise detail and certainty in the shape of components such as levers, retorts and cylinders.

Matthews's family insisted that he was of sound mind and offered guarantees of his good behaviour on condition of his release. In 1809, the family was allowed to hire doctors Henry Clutterbuck and George Birkbeck to independently examine Matthews. The doctors concluded that Matthews was not insane and that his behaviour, which included hostility to the authorities and a belief in a conspiracy against him, may have been a reaction to his unjust imprisonment. The family filed for Habeas Corpus, demanding an explanation of the legal grounds for his detention. In response, Haslam wrote a lengthy statement describing Matthews' delusions and claiming that he had allegedly threatened the life of George III. Ultimately, however, the Home Secretary recommended that Matthews' detention be continued, and the Habeas Corpus application was rejected. Matthews therefore remained under government supervision in a hospital, as a political prisoner accused of insanity.

Ironically, the publication of Illustrations of Madness brought Matthews some recognition. The drawing of the ‘aerial loom’ aroused the curiosity of visiting doctors, and Matthews began to study drawing and engraving on his own. Soon he even created architectural plans for the new Bethlem Hospital, which impressed the governors so much that he was awarded a £30 reward. In 1814, his family managed to transfer him to the more comfortable shelter of Fox's London House in Hackney, where Dr Samuel Fox deemed him fully sane. Matthews took up accounting and gardening.

Following Matthews' death in 1815, an inquiry into conditions in mental hospitals, including Bethlem, was launched in the House of Commons. Haslam accused the hospital staff of incompetence and abuse, including alcohol consumption and patient abuse. One of the head gatekeepers testified that Haslam kept Matthews in handcuffs to 'punish him for his words'.

When the Committee's report was published in 1816, the governors of Bethlehem forced Haslam to resign. This ruined his career, and he was forced to retrain, obtain a doctorate in medicine, and become an expert witness in criminal insanity trials. Matthews's case left a deep mark on his worldview: he was no longer confident in being able to clearly distinguish between the sane and the insane. In his old age, when asked whether the defendant was of sound mind, Haslam replied: 'I have never seen a single person who was in his right mind.'

The story of James Tilley Matthews highlighted the early need for a humane approach to psychiatry and the importance of understanding and studying mental disorders. His case is a vivid example that illustrates the first attempts to describe paranoid delusions scientifically and draws attention to the importance of investigating the mental state of patients instead of isolating and mistreating them.

Thus, the history of psychiatry is a complex and controversial journey that reflects the evolution of human attitudes towards mental illness and its treatment. Isolating and often cruel approaches such as trepanation, bloodletting, and other early methods were based on limited knowledge and societal fears of the unexplainable. The case of James Tilley Matthews became a landmark not only because of its uniqueness, but also because it drew attention to the need for a humane approach to treatment.

The condemnation of practices that violated patients' rights contributed to a gradual transition to more scientific and tolerant treatment methods. Over time, new approaches, such as psychotherapy and medication therapy, have emerged to help patients without coercion or suffering. This path of evolution shows the importance of compassion, professionalism and understanding of mental health.

Today, psychiatry not only studies but also seeks to rehabilitate and integrate people with mental disorders into society, which is evidence of significant progress towards humanisation. Matthews's case reminds us that understanding, not suspicion and fear, should be the basis of the approach to treating mental illness, ensuring that everyone has the right to be treated with dignity and to live with dignity.

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TRANSPORT TECHNOLOGIES

Abbasov S.M.

PROSPECTS FOR ELECTRIC VEHICLE DEPLOYMENT

Language Advisor – Senior Lecturer Ivanova I.L.

Electric mobility offers a low cost of travel along with energy savings and reductions in harmful emissions. Nevertheless, a comprehensive literature review on the prospects of electric vehicles (EVs) in developing countries is currently lacking. Such an overview would be invaluable for policymakers to better understand the barriers and opportunities related to different types of electric vehicles. Following the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines, a systematic review was performed using the electronic databases Google Scholar and Web of Science covering studies from 2010 to 2020. The review focused on electric four-wheelers, hybrid electric vehicles, and electric two-wheelers. Initially, 35 studies from Web of Science that met the criteria were analyzed. Subsequently, 105 additional relevant reports and articles related to barriers and opportunities were identified through Google Scholar and studied. The findings reveal that electric four-wheelers are not a feasible option in developing countries due to their high purchase price. On the contrary, electric two-wheelers could offer significant benefits due to their lower purchase price.

In 2023, nearly 14 million new electric cars were registered globally, bringing the total number on the roads to 40 million and closely aligning with the sales forecast in the 2023 edition of the Global EV Outlook (GEVO-2023). Electric car sales in 2023 were 3.5 million higher than in 2022, marking a 35% year-on-year increase. This is more than six times higher than in 2018, just 5 years earlier. In 2023, weekly registrations exceeded 250,000, which is more than the annual total in 2013, ten years earlier. Electric cars accounted for around 18% of all cars sold in 2023, up from 14% in 2022 and only 2% in 2018. These trends indicate that growth remains strong as electric car markets mature. Battery electric vehicles accounted for 70% of the electric car stock in 2023.

While sales of electric cars are increasing globally, they remain significantly concentrated in a few major markets. In 2023, just under 60% of new electric car registrations occurred in the People's Republic of China (hereafter 'China'), nearly 25% in Europe, and around 10% in the United States – together accounting for nearly 95% of global electric car sales. In these countries, electric cars represent a large share of local car markets: in 2023, more than one in three new car registrations in China was electric in, over one in five in Europe, and one in ten in the United States. However, sales remain limited elsewhere, even in countries with developed car markets such as Japan and India. As a result of sales concentration, the global electric car stock is also increasingly concentrated. Nevertheless, China, Europe and the United States also represent around two-thirds of total car sales and stocks, meaning that the EV transition in these markets has major repercussions in terms of global trends.

In China, the number of new electric car registrations reached 8.1 million in 2023, increasing by 35% compared to 2022. Rising electric car sales were the main reason driving growth in the overall car market, which contracted by 8% for conventional (internal combustion engine) cars but grew by 5% in total, indicating that electric car sales continue to perform well as the market matures. The year

2023 was the first in which China's New Energy Vehicle (NEV) industry operated without national subsidies for EV purchases, which had facilitated expansion of the market for more than a decade. However, a tax exemption for EV purchases and non-financial support hold steady after an extension, as the automotive industry is seen as one of the key drivers of economic growth. Some province-led support and investment also remain in place and plays an important role in China's EV landscape. As the market matures, the industry is entering a phase marked by increased price competition and consolidation. In addition, China exported over 4 million cars in 2023, making it the largest auto exporter in the world, with 1.2 million of these exports being EVs. This is significantly more than the previous year – overall car exports were almost 65% higher than in 2022, and electric car exports were 80% higher. The main export markets for these vehicles were Europe and countries in the Asia-Pacific region, such as Thailand and Australia.

Most charging still occurs at home or work, with the number of private chargers being ten times higher than public ones**.** The United Kingdom has one of the highest shares of home charging access, at 97%. However, the more electric vehicles hit the roads, the more public charging points are needed to support the widespread EV adoption, especially in densely populated areas where access to home charging is more limited. In 2023, the public charging stock rose by around 40%**.** Fast chargers, specifically, accounted for 35% of the public charging stock by the end of the year and outpaced the growth of slow chargers. For both slow AC charging and fast DC charging, China dominated the market in 2023, with over 85% of the world's fast chargers and 60% of slow chargers installed in the country over the year.

Heavy-duty vehicles can generally charge at the same charge points as light-duty vehicles, but he larger the battery, the longer the charging time. Charging heavy-duty vehicles can therefore result in disruptions and delays at regular charging facilities. Dedicated charging spaces for heavy-duty vehicles are greatly needed, but their development is still in its infancy. To prepare for the wave of HDEVs, there's a strong need for a network of ultra-fast (HPC) chargers and a new charging standard that further reduces the charging times. Luckily, both are in development. The AFIR states that heavy-duty electric vehicles must be able to charge with a minimum output of 350 kW every 60 kilometers along the core TEN-T network and every 100 kilometers along the larger TEN-T network. A new charging standard, the megawatt charging standard (MCS), which allows charging capacity up to 3.75 MW has been in development since 2019. The standard is now being tested by the CharIN association, which is responsible for developing the system, and it should become the industry standard for heavy-duty charging by 2025.

Electric buses have been growing in popularity since 2020. In 2023, almost 50 000 electric buses were sold globally, bringing the global stock to over 635 000. China dominated the market in 2020, when it was responsible for over 90% of electric bus sales, but in 2023, the Chinese demand dropped. This could be due to its already large electric bus stock and the end of purchase subsidies. The country still remains a major exporter to Latin American, North American and European countries. In the European Union countries, the Clean Vehicles Directive provides targets for public procurement of electric buses. France, Germany, and Spain are only a few EU countries seeing increased electric bus sales. Belgium, Norway and Switzerland achieved a sales share of over 50% in 2023.

The automotive engine is combined with a less carbon-intensive power industry. Electric vehicles have no tailpipe emissions and are more efficient than internal combustion engine vehicles (ICEVs), offering enormous potential for reducing CO2 emissions from gasoline. Although EVs provide a viable way to lessen dependence on fossil fuels and greenhouse gas emissions, challenges such as torque ripple in brushless DC (BLDC) motors still exist.

The shift to electric mobility offers significant advantages, including reduced oil dependence and enhanced environmental health. Electric vehicles, which exemplify this transition, are known for their lower energy consumption and zero greenhouse gas GHG emissions. As a result, many developed nations are promoting the adoption of EVs to reduce air pollution, CO 2 emissions, and other greenhouse gases.

Electric two and three-wheelers accounted for 13% of total sales in 2023 making it the most electrified vehicle segment globally. Historically, China dominated the electric two-wheeler market, but in 2023, the sales fell globally by a quarter. This drop wasn't unique to China as the sales dropped globally by 18%. This decline was mainly caused by supply bottlenecks following the Covid-19 pandemic. In terms of electric three-wheelers, sales grew by 30% compared to 2022. China and India together account for nearly 95% of global sales.

Overall, the transition to electric mobility is a crucial step toward achieving global environmental goals, reducing dependence on fossil fuels, and promoting sustainable growth. Despite current challenges, technological advancements, strategic policies, and international cooperation will be essential in maintaining and expanding the momentum for electric vehicles worldwide. This progress will help create a cleaner, more efficient, and equitable transport future.

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Biletskyi D. O.

CAREERS IN LOGISTICS AND SUPPLY CHAIN: OPPORTUNITIES AND CHALLENGES

Language Advisor – Asst. Prof. Chevychelova O. O.

Logistics and supply chain management are essential components of modern commerce, influencing how goods and services move efficiently across the globe. These interconnected fields offer a wide range of career opportunities for individuals with diverse skills and interests. The increasing complexity of global trade and consumer expectations has transformed logistics and supply chain operations, making them vital to economic success.

The roles within logistics and supply chains are varied, encompassing everything from inventory management and procurement to transportation and distribution. Entry-level positions often include roles like warehouse operatives, transportation planners, or inventory controllers, which provide hands-on experience and a foundational understanding of the field. For those with expertise or advanced education, positions like supply chain analysts, procurement specialists, and logistics managers offer opportunities to shape and optimise the flow of goods and services.

Technology plays a pivotal role in modern logistics and supply chain operations. Automation, artificial intelligence, and data analytics have revolutionised how businesses forecast demand, manage inventory, and track shipments. These technologies require skilled professionals capable of integrating advanced systems into supply chain processes. As e-commerce continues to expand, roles in last-mile delivery and fulfilment centers are in high demand, offering both challenges and rewards for those interested in logistics.

One of the key factors attracting individuals to logistics and supply chain careers is the global nature of the industry. Professionals often interact with international suppliers, manufacturers, and customers, providing opportunities for travel and cross-cultural experiences. Additionally, these roles are integral to addressing critical global challenges, such as reducing carbon emissions and improving sustainability practices.

However, working in logistics and supply chain management also presents unique challenges. The sector is highly dynamic, requiring professionals to adapt to changing regulations, economic fluctuations, and unforeseen disruptions like natural disasters or pandemics. Effective communication, problem-solving, and decision-making skills are essential for navigating these complexities.

Education and training play a significant role in preparing individuals for careers in logistics and supply chain management. Academic programs ranging from certificates to advanced degrees equip students with the knowledge and skills needed to succeed in this field. Additionally, professional certifications, such as the Certified Supply Chain Professional (CSCP) or the Certified Logistics Associate (CLA), provide valuable credentials for career advancement.

The impact of globalization cannot be overstated when considering the future of logistics and supply chain careers. The growing interconnectedness of economies demands professionals who can navigate international markets, manage trade agreements, and respond to geopolitical shifts. The ability to anticipate and adapt to global trends is becoming a hallmark of successful supply chain professionals.

Another emerging area in logistics and supply chain management is the circular economy. This concept focuses on reducing waste and reusing resources, challenging traditional linear supply chain models. Professionals in this field are now tasked with finding innovative ways to repurpose materials and minimise environmental impact, aligning operations with sustainable development goals.

In addition to technological advancements, the increasing emphasis on corporate social responsibility is influencing the logistics and supply chain sector. Organisations are investing in sustainable practices, such as using energy-efficient transportation methods, minimising waste in packaging, and promoting ethical labour practices throughout the supply chain. These trends underscore the growing demand for professionals who can balance economic objectives with environmental and social considerations.

Furthermore, the COVID-19 pandemic highlighted the importance of resilient and adaptable supply chains. Businesses worldwide experienced disruptions, emphasising the need for agile logistics strategies and contingency planning. This shift has increased the demand for skilled professionals who can anticipate risks, manage disruptions, and ensure supply chain continuity.

As globalisation continues to expand, so do opportunities in logistics and supply chain management. With increased international trade, the need for professionals capable of navigating complex global networks is at an all-time high. From managing tariffs and customs regulations to understanding cultural nuances in international business, these careers offer a unique blend of strategic thinking and operational execution.

In conclusion, logistics and supply chain management offer dynamic and rewarding career paths for individuals passionate about problem-solving, efficiency, and global connectivity. As the industry continues to evolve, professionals in this field will play a critical role in shaping how goods and services move in a rapidly changing world. The opportunities for growth, innovation, and impact make logistics and supply chain careers an exciting choice for those looking to make a difference in the modern economy.

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Bludov D.O.

THE IMPACT OF AUTOMOBILES ON MOBILITY, ECONOMY AND ENVIRONMENT

Language Advisor – Senior Lecturer Ivanova I.L.

Cars provided individuals with unprecedented mobility, enabling them to travel longer distances, reach new destinations, and access opportunities that were once out of reach. What began as a luxury for the wealthy became accessible to the broader population, significantly changing daily life.

A key factor in the widespread use of automobiles was the development of infrastructure. The construction of highways, bridges, and fueling stations made it easier for people to drive, and the automobile became an essential tool for personal and professional life. Over the years, advancements in vehicle technology, such as electric cars and self-driving vehicles, have further expanded the possibilities for personal mobility, promising even more profound changes in how we will travel in the future.

The automobile industry plays a critical role in the global economy. It not only includes the manufacturers of vehicles, but also the production of parts, fuel distribution, logistics, insurance, and a variety of other sectors that rely on automobiles. The automotive industry creates millions of jobs worldwide, contributing significantly to both local and national economies.

Additionally, automobiles have facilitated trade and globalization. Cars, trucks, and other vehicles are crucial for transporting goods across regions and countries. This has driven the growth of global supply chains and allowed for the rapid movement of products, which in turn stimulates economic development and opens new markets for businesses.

While automobiles have brought many benefits, their widespread use has also led to significant environmental challenges. Traditional vehicles powered by gasoline and diesel are major contributors to air pollution, greenhouse gas emissions, and climate change. The transportation sector accounts for a significant portion of global carbon emissions, making it a critical area of focus for environmental policy.

However, the automotive industry has been taking steps toward more sustainable solutions. The rise of electric vehicles (EVs), hybrid cars, and hydrogen-powered vehicles offers hope for reducing the environmental impact of transportation. As battery technology improves and governments implement stricter emissions standards, electric vehicles are becoming more accessible and are expected to play a major role in the future of transportation.

The growing number of cars on the road has led to significant changes in urban infrastructure. In large cities, traffic congestion, a lack of parking spaces, and road maintenance have become major issues. Air pollution and noise pollution, too, are increasingly affecting the quality of life for urban dwellers.

In response to these challenges, cities are beginning to rethink their approach to urban planning. Many are investing in public transportation systems, creating bike lanes, and expanding pedestrian zones to reduce reliance on personal vehicles. The concept of "smart cities" is also gaining traction, where technology is used to manage traffic, optimize transportation networks, and reduce environmental impacts. These efforts aim to create a more sustainable and efficient urban environment.

Automobiles have also had a profound impact on culture and social behavior. In some societies, owning a car is seen as a symbol of status, independence, and success. In many parts of the world, especially in the United States, cars have become deeply embedded in the way people live and work.

At the same time, the automobile industry has influenced cultural trends, from car design and advertising to the rise of road trips and the development of car-related subcultures. Cars have also contributed to the spread of mass media, as they provide the mobility necessary for people to attend events, concerts, and social gatherings.

However, the widespread dependence on cars has also led to changes in social dynamics. In many urban areas, long commutes and traffic jams have affected people's daily routines, reducing the amount of time they spend with family and friends. In rural areas, where public transportation is less developed, cars are often essential for social interaction and access to services.

In conclusion, it is important to acknowledge that automobiles have profoundly impacted modern society, shaping everything from personal mobility and economic structures to urban planning and cultural practices. While they have brought tremendous benefits, such as increased accessibility and economic growth, they have also posed significant environmental challenges. As we move toward a more sustainable future, the automobile industry must continue to innovate and address the pressing issues of climate change, pollution, and urban congestion.

The future of transportation will likely involve a shift toward cleaner, more efficient technologies, such as electric and autonomous vehicles. By embracing these innovations, we can ensure that automobiles continue to improve our lives while minimizing their negative impact on the planet.

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Boiko V. Yu.

PROSPECTS OF USING ELECTRIC VEHICLES TO IMPROVE ROAD TRAFFIC EFFICIENCY

Scientific Advisor – Cand. Eng. Sc, Assoc. Prof. Shirin V. V.
Language Advisor – Cand. Ped. Sc., Assoc. Prof. Skrypnyk N. S.

A primary trend in the development of the world economy in the 21st century is the widespread use of new environmental technologies. The introduction of legislative initiatives to limit emissions of harmful substances has also affected the global automotive market. An increasing number automotive companies and their customers are abandoning the production of traditional cars with an internal combustion engine. At the same time, the production of electric vehicles is growing rapidly, becoming more affordable.

The purpose of the study is to determine the prospects for integrating electric vehicles into the street and road network of urban agglomerations to enhance the efficiency and environmental sustainability of road traffic.

First of all, it should be noted that electric vehicles represent a large group of vehicles characterized primarily by their use of electricity for movement (Alanazi, 2023). Today, the production of battery electric vehicles and plug-in hybrid electric vehicles is growing most rapidly, driven by the specific features of their design.

Battery electric vehicles rely solely on batteries as their source of energy. Consequently, the range of these electric vehicles directly depends on the battery capacity. Typically, they can travel between 100 and 250 km on a single charge, while the most advanced models can go much farther, from 300 km to 600 km. Due to the absence of exhaust emissions, battery electric vehicles are the most environmentally friendly type of electric vehicle.

Plug-in hybrid electric vehicles, unlike traditional hybrids, can be charged from external sources of electricity (e.g., charging stations). They use electric power as the primary driving force for short distances, while an internal combustion engine is used for longer trips and to recharge the battery. The ability of a plug-in hybrid electric vehicle to operate solely on electricity for extended periods reduces its carbon footprint compared to that of a conventional hybrid vehicle (Un-Noor, 2023).

The growth in electric vehicle sales has also been observed in Ukraine. In 2024, the company "Pro-Consulting" conducted an analysis of the electric vehicle market in Ukraine for the Association of Ukrainian Automobile Manufacturers "UkrAvtoprom." According to their data, there was an increase in sales of both new and used electric vehicles from 2021 to 2023 (3). A clear example of this growth is that in 2021, the share of used electric vehicles sold was 1.1% of the total, while in 2023, their share had already reached 8% (Table 1).

Table 1. Car sales segments in Ukraine in 2021-2023, new and used, units and %

	2021		2022		2023	
New	143863	20,5%	65247	12,2%	114389	30,3%
Electric Vehicles	1500	0,2%	2312	0,4%	7520	2,0%
Other	142363	20,3%	62935	11,8%	106869	28,3%
Used	557400	79,5%	469619	87,8%	262674	69,7%
Electric Vehicles	7372	1,1%	11288	2,1%	30080	8,0%
Other	550028	72,8%	458331	85,7%	232594	61,7%
Total	701263	100,0%	534866	100,0%	377063	100,0%

These data indicate an increase in the number of customers interested in purchasing electric vehicles. One factor positively impacting this increase is the growing environmental awareness among the population. Additionally, the National Transport Strategy of Ukraine for the period up to 2030 (4) has a positive effect on consumers' preference for environmentally friendly vehicles. According to this strategy, there are plans to increase the share of electric transport and electric vehicles, specifically aiming to raise the share of electric transport in domestic traffic to 75 percent.

When examining the use of electric vehicles to improve traffic efficiency in Ukrainian cities, it is important to note that there are four categories of traffic efficiency indicators: technical, social, environmental, and economic (Figure 1).

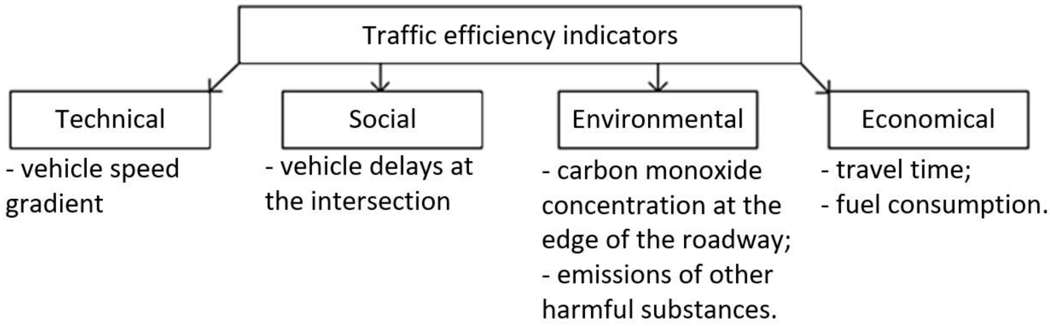

Figure 1. Traffic efficiency indicators

It can be confidently stated that the gradual increase in the fleet of electric vehicles in Ukraine will have a significant impact on the efficiency of road traffic in Ukrainian cities.

Thus, the use of electric vehicles in urban traffic conditions, especially when combined with adaptive cruise control technologies, will significantly reduce abrupt speed fluctuations, which will affect the speed gradient. This will also help to substantially reduce the load on road infrastructure, which is particularly relevant in challenging financial conditions.

Thanks to the ability of electric vehicles to move more smoothly and efficiently, delays in traffic jams and at intersections are reduced. Electric vehicles equipped with energy recovery technologies are better suited to urban conditions, where frequent stops and accelerations occur. It is also worth noting that the electric motor operates almost silently, which significantly reduces noise pollution in cities. In other words, the use of electric vehicles helps improve traffic flow and enhances the comfort of both the driver and other road users.

The environmental performance of road traffic is most affected by electric vehicles. A gradual increase in the share of electric vehicles in the traffic flow will lead to a significant reduction in emissions of harmful substances in cities, especially in areas of high traffic density, which will improve air quality and environmental conditions in Ukrainian cities.

Equally important is the impact of electric vehicles on an economic indicator such as fuel consumption, as this expense is one of the largest for owners of internal combustion engine vehicles. Battery electric vehicles do not require petroleum fuel at all, while plug-in hybrids can partially operate on electric power during city trips, significantly reducing fuel costs.

In conclusion, we can say that the use of electric vehicles in Ukrainian cities is justified. Battery electric vehicles and plug-in hybrids will significantly impact road traffic efficiency. Changes in indicators such as harmful emissions levels and fuel consumption will be particularly noticeable.

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Bondarenko D. I.

DEVELOPMENT OF CHARGING INFRASTRUCTURE FOR ELECTRIC TRANSPORT

Scientific Advisor – CandSc (Engineering), Assoc. Prof. Dziubenko O. A.
Language Advisor – CandSc (Education), Assoc. Prof. Borzenko O. P.

The National economic strategy recognizes the need to achieve climate neutrality no later than 2060. Also, reducing the total volume of pollutant emissions into the atmosphere from mobile sources, conventionally reduced to carbon monoxide, taking into account the relative aggressiveness of the main pollutants, to 70% (from the 2015 level) is one of the priorities of the National transport strategy for the period until 2030 (Мельник, 2022).

As for the vehicle fleet electrification, in recent years Ukraine has seen an increase in sales of electric vehicles, which was facilitated by stimulating measures of state policy. In 2016, the duty on electric vehicles was abolished, and since 2018, excise tax and VAT on the import of electric vehicles were abolished. As a result (Fig. 1), in 2014 only 62 electric vehicles were sold (0.07% of total sales), in 2016 – 1148 electric vehicles (1.5%), in 2019 – 7012 (7.2%). Currently, Ukraine is among the top 12 European countries in terms of the total number of electric vehicles and demonstrates one of the highest rates of vehicle fleet electrification (Мельник, 2022).

According to the Automotive Market Research Institute, in August alone (2024 – author's note), Ukrainians purchased almost 9.4 thousand new and used electric vehicles.

This became an absolute monthly record since 2014, for the entire period of sales of electric vehicles in Ukraine.

If we count from the beginning of the year, then over 54.8 thousand electric vehicles were purchased in eight months, which is already more than for the whole of 2023 (Куницький & Пшемиська, 2024).

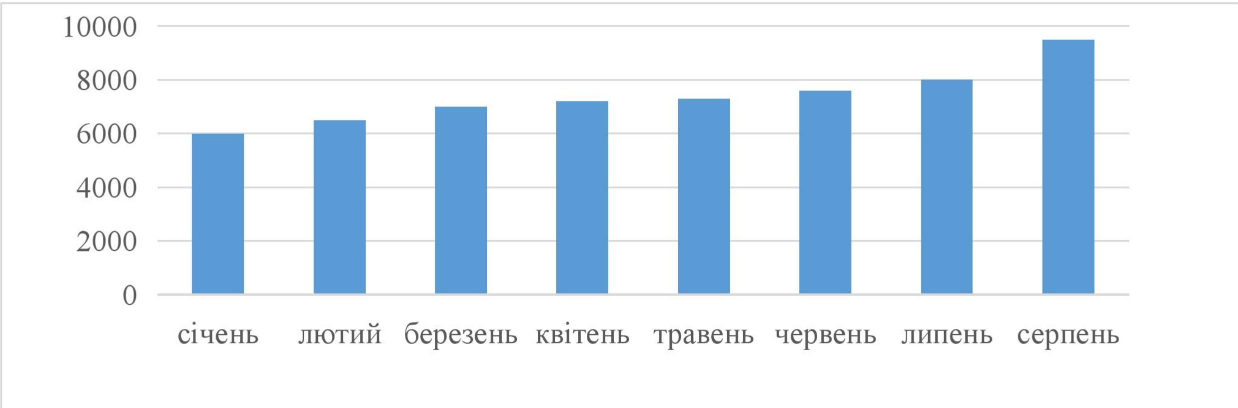

Fig. 1 – Dynamics of electric vehicle sales in Ukraine for eight months of 2024

Most of the imported vehicles are used vehicles from Europe, Asia and the USA. Despite growing demand, the charging infrastructure in Ukraine is not sufficiently developed. As of the end of 2021, there are more than 15 charging station operators, 3244 charging stations, 7661 charging points / connectors, of which "slow" AC ≤ 22 kW (Type 1, Type 2, J 1772) – 5826 (76%); "fast" DC ≥ 22 kW (CCS 1, CCS 2, CHAdeMO, GB\T) – 1835 (24%) (Мороз, 2021).

At the same time, the main number of charging stations is concentrated in large cities (Kyiv, Lviv, Kharkiv, Odesa) and along central highways (PlugShare, 2024). There is an imbalance in favor of "slow" stations (up to 22 kW). This is not enough to meet the needs of the current electric vehicle fleet, especially given its growth rate. The variety of charging standards in use also complicates the situation.

The development of charging infrastructure will create new jobs, attract investment in the transport sector; the spread of electric vehicles, as one of the consequences, will reduce air pollution in cities with heavy traffic and reduce CO_2 emissions.

The aim of the research is to develop proposals for unifying the process of charging electric vehicles in Ukraine, taking into account global experience.

There are currently several standards for electric vehicle charging stations. The IEC 62196 standard, originally implemented in 2003 by the International Electrotechnical Commission and amended over time, is global and covers all existing vehicle charging configurations.

Part 3 of the IEC 62196 standard was published in 2014, subsequently supplemented and republished in 2024. This is due to the availability of direct current charging for electric vehicles, which has made the charging process more efficient due to the ability to use higher power current without converting it by vehicle units – the conversion of alternating current to direct current occurs directly at the charging station.

The AA type connector (according to IEC 62196 standard), also known as the CHADeMO (from "Charge de move") system, was developed in 2010 by the Japan Automobile Manufacturers Association. First generation CHAdeMO connectors provide up to 62.5 kW at 500 V. The second generation specification allows up to 400 kW at 1 kV, 400 A.

The third generation of the system, which has the working name “ChaoJi” and aims to provide charging with current capacity of up to 900 kW, will be developed in the future. The ChaoJi connector will be compatible with the CHAdeMO system and the GB/T standard (CHAdeMO, 2024).

The type BB connector according to IEC 62196 standard is consistent with the connector specified in Part 3 of the Chinese GB/T 20234 standard and is designed for use with DC charging stations supporting CAN bus communication. Charging is carried out with direct current, single-phase current with a voltage from 750 to 1000 V, with a power up to 250 kW.

The Type EE and Type FF connectors implemented by the IEC 62196 standard, also known as “Combo 1” and “Combo 2” or CCS 1 and CCS 2 (from Combined Charging Standard), respectively, are combined and allow charging with both alternating and direct current. The EE connector ("Combo 1", CCS 1) is used in North America, while the CCS 2 standard was implemented as a global standard.

CCS standards support single-phase alternating current charging similar to the Type 1 and Type 2 connector and direct current charging at voltages from 200 to 920 V and power up to 350 kW using high power charging (HPC) technology.

Vehicle manufacturer Tesla equips its branded Tesla Supercharger stations with a unique connector, thanks to which charging is available only for vehicles of this manufacturer. However, since 2001 the standard has been opened up for use by other manufacturers and now Tesla Superchargers can be used by Ford electric vehicles, and the connector is also backwards compatible with the combined CCS 1 that is common in North America. New Tesla Model 3 vehicles are equipped with a combined CCS 2 for use with charging stations in Europe. Tesla Supercharger technical specifications: charging power up to 250 kW (depending on model), direct current voltage up to 480 V (Joint Office, 2024).

An analysis of existing standards, the types of connectors regulated by them and chargers shows that their diversity creates certain problems for the mass implementation of electric vehicles and the development of infrastructure. Thus, the aim of the research should be to assess the prospects for the implementation of innovative technologies in the field of charging stations, develop recommendations for improving the charging infrastructure, study existing global standards and form a conclusion about their implementation in Ukraine in order to unify processes. Achieving the defined goal requires additional research.

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Brykulskyi O.V.

RETHINKING URBAN MOBILITY: THE FUTURE OF ROAD SYSTEMS IN SMART CITIES

Language Advisor – Lecturer Lukianenko N.M.

As urban populations grow, the need for efficient and sustainable road systems becomes paramount. This paper explores innovative approaches to urban mobility within smart cities, emphasizing the integration of technology, multimodal transport, and sustainable practices. By examining current trends and future possibilities, it highlights the potential for adaptive road systems that cater to the evolving needs of urban environments.

The 21st century has seen unprecedented urbanization, with more than half of the global population now residing in cities. This shift presents significant challenges for existing transportation systems, which often struggle to accommodate increasing traffic volumes and environmental concerns. The need for a comprehensive rethink of urban mobility is critical, focusing on innovative solutions that leverage technology and promote sustainability. This article examines the future of road systems in smart cities, underscoring the importance of integration, multimodality, and resilience.

The Urban Mobility Challenge.

Urban areas are experiencing a surge in population density, leading to various mobility challenges. Traffic congestion, air pollution, and inadequate infrastructure are pressing issues that need immediate attention. According to recent studies, urban areas contribute significantly to global greenhouse gas emissions, necessitating the adoption of more sustainable transport options (Offen, 2023; Jones & Roberts, 2021).

The reliance on personal vehicles has exacerbated these issues, resulting in sprawling urban landscapes and increased congestion. Traditional road systems are ill-equipped to handle the demands of modern urban life. Therefore, innovative approaches that prioritize efficiency and sustainability are essential.

The Role of Smart Technologies.

Intelligent Transportation Systems (ITS) utilize technology to optimize traffic management and improve road safety. These systems can collect and analyze data in real-time, enabling cities to make informed decisions about traffic flow and infrastructure development. For instance, adaptive traffic signals can adjust their timing based on current conditions, reducing congestion and enhancing safety (Offen, 2023; Smith et al., 2022).

By implementing smart traffic management systems, cities can better allocate resources and respond to changing traffic patterns. This not only alleviates congestion but also minimizes environmental impact. ITS can seamlessly connect various modes of transport, making it easier for users to transition between buses, trains, and rideshare services. Such integration encourages the use of public transport and reduces reliance on personal vehicles. The rise of autonomous vehicles (AVs) represents a paradigm shift in urban mobility. These vehicles can significantly enhance road safety and reduce traffic congestion. Equipped with advanced sensors and algorithms, AVs can navigate complex environments more efficiently than human drivers.

Sustainable Infrastructure.

Designing future road systems with sustainability in mind is essential. Green road design incorporates environmentally friendly practices that minimize ecological impact and enhance urban resilience. Utilizing permeable materials for road surfaces can reduce stormwater runoff and improve water quality. This approach not only benefits the environment but also decreases the risk of flooding in urban areas (Smith et al., 2022). Integrating green spaces within road systems—such as parks and tree-lined streets—enhances air quality and provides recreational opportunities for residents.

Incorporating renewable energy sources, such as solar panels on noise barriers or charging stations for electric vehicles, can contribute to a more sustainable transportation network.

Climate Resilience.

As climate change continues to pose risks to urban infrastructure, future road systems must be designed to withstand extreme weather events. Cities need to adopt strategies that enhance resilience, including: implementing flood-resistant materials and elevated roadways in vulnerable areas can mitigate damage from heavy rainfall and rising sea levels. Employing materials that can withstand extreme heat will ensure the durability of road systems, especially in warmer climates. Cities must develop comprehensive plans to adapt to climate impacts, ensuring that transportation infrastructure remains functional and safe during extreme weather events.

The future of road systems in smart cities hinges on the integration of technology, multimodal transportation solutions, and sustainable practices. As urban populations continue to grow, innovative approaches to urban mobility will be essential in addressing congestion, reducing emissions, and improving overall quality of life. By learning from successful case studies and prioritizing equity and accessibility, cities can create adaptive road systems that meet the evolving needs of their residents.

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Dmytriieva V. S.

ADVANCEMENTS IN TRANSPORT TECHNOLOGIES: SHAPING THE FUTURE OF MOBILITY

Language Advisor – Asst. Prof. Chevychelova O. O.

Transport technologies have always been a driving force behind societal progress, fueling economic growth, enhancing connectivity, and enabling trade. In the 21st century, the landscape of transport is being reshaped by innovations that focus on improving efficiency, sustainability, and accessibility. This evolution is centered around smart transportation systems, alternative energy vehicles, autonomous technologies, and emerging trends.

Smart transportation systems are revolutionizing urban mobility by integrating information and communication technologies (ICT) into transport networks. Intelligent traffic management, for example, uses real-time data to adjust traffic signals dynamically, reducing congestion and emissions. Public transit innovations, such as smart card payment systems and real-time tracking apps, make commuting more efficient and user-friendly. Additionally, the Internet of Things (IoT) is enhancing transport infrastructure with sensors that enable predictive maintenance and real-time updates for road users. Integrated Mobility-as-a-Service (MaaS) platforms are also making travel more seamless, combining various modes of transport into a single service for greater convenience.

The shift to alternative energy vehicles is a key response to climate change concerns and the need to reduce fossil fuel reliance. Electric vehicles (EVs), which are increasingly being adopted for their zero-emission benefits, are advancing in terms of range, charging times, and cost. Hybrid vehicles, combining traditional engines with electric motors, serve as a bridge between conventional and fully electric transportation. Emerging technologies like solar-powered vehicles and biofuels also contribute to sustainable transport options, offering solutions for niche markets and specific industries like aviation.

Autonomous technologies are rapidly transforming transport systems by removing the need for human drivers. Self-driving cars are advancing towards full autonomy, using sophisticated sensors and machine learning to improve road safety and efficiency. Autonomous buses and shuttles are being trialed in urban areas to provide cost-effective public transport solutions, while drone deliveries are making logistics faster and more efficient. Autonomous freight solutions, including trucks and ships, promise to optimize supply chains and reduce human error, further enhancing the logistics sector.

While the advancements in transport technologies present exciting possibilities, they also come with challenges. Upgrading infrastructure to support these innovations requires substantial investment, particularly in areas like electric vehicle charging networks. Additionally, regulatory frameworks must evolve to ensure safety, privacy, and equitable access, especially for autonomous vehicles and drones. Technological standardisation and cybersecurity are also critical to ensuring seamless integration and protecting transport systems from potential threats.

As transport technologies evolve, the importance of collaboration between public and private sectors becomes increasingly clear. Governments must invest in the necessary infrastructure and ensure regulatory frameworks are in place to support innovation while maintaining safety and equity. Partnerships with private companies, particularly those in technology and infrastructure development, can accelerate the deployment of new systems, such as electric vehicle charging stations and autonomous vehicle trials. Public-private collaboration also plays a crucial role in addressing the environmental impact of transportation, with incentives and policies that encourage the adoption of cleaner, more sustainable technologies.

Emerging trends are further shaping the future of transport. Hyperloop systems, which aim to revolutionise long-distance travel with ultra-fast transportation through vacuum tubes, are gaining traction with companies like Virgin Hyperloop leading the charge. Shared mobility solutions such as ride-sharing and bike-sharing are reducing congestion in urban areas, while urban air mobility (UAM) with electric vertical takeoff and landing (eVTOL) aircraft could address urban congestion by providing aerial transport. Cities are also increasingly prioritising sustainable infrastructure, incorporating green technologies like solar-powered charging stations and eco-friendly materials into their transport networks.

In addition to technological advancements, cultural and behavioural shifts will be pivotal in shaping the future of transport. As people become more accustomed to shared mobility solutions and autonomous vehicles, new attitudes toward ownership and travel patterns are emerging. The rise of Mobility-as-a-Service (MaaS) platforms, for example, suggests a move away from personal vehicle ownership to a more flexible, on-demand approach to transportation. This shift has the potential to reduce urban congestion, lower carbon emissions, and create more sustainable and efficient transport systems. However, fostering this change will require education, awareness, and the building of trust in new technologies, particularly when it comes to safety and privacy concerns surrounding autonomous vehicles and data-sharing.

Advancements in transport technologies are poised to reshape how people and goods move, with an emphasis on efficiency, sustainability, and innovation. The global transport sector is moving towards a more connected and environmentally conscious future, with new developments offering significant opportunities to improve mobility and reduce the environmental impact of transport. However, overcoming the challenges posed by infrastructure, regulation, and standardisation will require cooperation across governments, industries, and research institutions. As emerging trends continue to develop, the transport landscape will evolve, creating new possibilities for how we travel and interact with the world around us.

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Fysun S. S.

THEORETICAL ASPECTS OF OPTIMIZATION OF DYNAMIC PROPERTIES OF ELECTRO-PNEUMATIC CLUTCH ACTUATOR CONTROL SYSTEMS

Scientific Advisor – CandSc (Engineering), Assoc. Prof. Yaryta O. O.
Language Advisor – CandSc (Education), Assoc. Prof. Borzenko O. P.

Electro-pneumatic clutch actuators play an important role in modern transmissions, providing a smooth and reliable gear shifting and starting process for various vehicles. Given the rapid development of technologies and increasing requirements for the characteristics of transmission unit control elements, the issue of optimizing their dynamic properties is becoming relevant.

The electro-pneumatic clutch actuator control system must provide high accuracy and speed of clutch disengagement, which is critically important for achieving high performance and safety of vehicles.

Existing control systems for electropneumatic clutch drives have a number of disadvantages that may limit their efficiency and reliability in the future. One of the main disadvantages is the delay in the system's response to control commands. In known systems, gear shifting can occur with a noticeable delay, which leads to a loss of driving dynamics and reduced driving comfort.

Pressure instability in the system is also a serious problem that requires attention. Temperature changes, mechanical loads and other factors can cause pressure fluctuations, which negatively affects the operation of the clutch actuator. Changes in pressure can cause a decrease in the operating accuracy and response speed of the actuator (Ярита, 2014, pp. 45-49).

Another important disadvantage is the difficulty of adapting the clutch actuator control system to changing operating conditions. In different situations, depending on driving conditions, the driver presses the clutch control pedal at different speeds, realizing different pedal stroke. In such cases, known systems may not provide the necessary flexibility in clutch control. This may worsen clutch performance and cause wheel slippage or jerks during gear shifting, which negatively affects driving comfort and safety (du Hongwang et al., 2018, pp. 511-519).

Modern systems require integration with other electronic vehicle systems, such as stability control and anti-lock braking systems. However, lack of compatibility between different control systems can lead to conflicts and decrease the overall efficiency of the vehicle.

As a result, all these issues create additional challenges for developers seeking to create reliable and efficient control systems.

Optimization of the dynamic properties of the electro-pneumatic clutch actuator control system will require a comprehensive approach covering both software and hardware components of the system. One of the key areas is the development of effective control algorithms that can take into account changing operating conditions and adapt to them. The use of proportional-integral-derivative controllers (PID controllers) may become standard practice in controlling such systems. They will be able to more accurately implement the necessary algorithms and ensure stable operation of the system. However, to solve the disadvantages of traditional PID controllers, it will be necessary to implement more modern adaptive methods.

Adaptive control algorithms will be able to dynamically change their parameters depending on current conditions. It is also worth noting the machine learning functions, which will allow the system to take into account data on previous clutch actuator operation modes and predict the necessary changes. Modernization of the control system hardware will be an important aspect of optimization. The use of high-speed valves with large flow rates can significantly reduce the time required to change the pressure in the system. The use of high-quality pressure and position sensors will provide more accurate and faster measurement of system operating parameters, which will increase control accuracy and reduce the probability of errors (Hazem et al., 2009, 440-454).

Integrating the electro-pneumatic clutch system with other vehicle systems such as stability control systems and engine control systems will also significantly improve overall performance. Interaction with systems that monitor road conditions and engine operating parameters will allow the creation of more adaptive control algorithms.

Using modeling and simulation methods to pre-test various system configurations will simplify and reduce the cost of the optimization process. These methods will allow analyzing the impact of various changes on the dynamic control properties and identifying disadvantages in the system's operation without the need to carry out physical tests.

The application of optimized electro-pneumatic clutch actuators control systems in the future promises significant results that emphasize the importance of innovative approaches in this area. It is expected that one of the most noticeable results will be an increase in system response speed. Reducing wear of transmission elements will also be a significant achievement (Ярита, 2014, 45-49). Thanks to more precise clutch control, optimized systems will be able to provide lower mechanical loads on all transmission components. In addition, smooth operation of the clutch will help to avoid sudden jolts and slippage, which, in turn, will lead to increased driving safety.

Vehicle control will be improved by integrating new control systems with existing safety and stability systems. This interaction will allow the clutch to more precisely adapt to road conditions and driving style, which will increase overall safety.

Finally, the use of modern technologies and approaches to the development of control systems will significantly increase the reliability and durability of the system. Control systems based on modern algorithms and equipment will demonstrate higher resistance to impacts and an increased level of protection from possible failures.

As a result of the research carried out and the implementation of optimized control systems, significant improvements in various aspects of electro-pneumatic clutch actuators are expected.

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Herasymov A.V.

MODELING THE BEHAVIOR OF AUTONOMOUS VEHICLES IN CHALLENGING ROAD CONDITIONS

Language Advisor – Senior Lecturer Ivanova I.L.

The development of autonomous vehicles (AVs) represents a revolutionary milestone in modern transportation, promising to transform mobility, reduce traffic accidents, and enhance fuel efficiency. However, to fully integrate into daily life, driverless cars must handle a wide range of road conditions, including complex and unpredictable situations. Such challenges may arise from adverse weather conditions like heavy rain, snow, or fog, as well as emergencies such as sudden vehicle breakdowns, accidents, or road debris. Modeling AV behavior in these challenging scenarios is crucial for their development and widespread adoption.

Driverless vehicles rely heavily on sensors, cameras, radar, and LiDAR for navigation and real-time decision-making. While these systems perform well under ideal conditions, real-world roads are far from perfect. Weather variability, unexpected hazards, and complex road environments shared with human-driven vehicles create significant challenges for the sensors and decision-making algorithms in AV systems.

Simulating AV behavior in controlled environments is essential to understand how these vehicles will perform in various scenarios. Accurate models allow engineers to test vehicle performance without exposing it to real-world dangers, enabling fine-tuning of sensor inputs, decision-making processes, and control algorithms before deployment on public roads. Essentially, simulation provides a safe space for AV developers to experiment, refine, and validate the vehicle's capabilities in diverse scenarios.

Factors that make modeling AV behavior in challenging road conditions particularly difficult include: weather conditions, sensor reliability, unpredictable road obstacles, dynamic traffic environments, and emergency scenarios.

Adverse weather conditions, such as heavy rain, snow, fog, and icy roads, pose significant challenges to the performance of autonomous vehicle sensors. Rain can reduce camera visibility, while snow often obscures critical road markings, making navigation difficult. Ice and slippery surfaces further complicate vehicle handling and stability, requiring advanced control systems to maintain safety.

Autonomous vehicles depend on a combination of sensors, including cameras, radar, ultrasonic sensors, and LiDAR, each with its own advantages and limitations. Cameras provide high-resolution images, but their performance diminishes in low-light or foggy conditions. Meanwhile, radar and LiDAR are more effective in poor visibility but remain susceptible to disruptions caused by rain or snow.

Complex road conditions often include unexpected hazards like debris, potholes, or stranded vehicles. AVs may need to make split-second decisions to avoid collisions or safely navigate around these obstacles. Simulating such scenarios requires advanced decision-making algorithms capable of adapting to sudden environmental changes.

Urban settings present particularly dynamic challenges for autonomous vehicles, as pedestrians, cyclists, and other vehicles frequently change their positions. Simulating the behavior of AVs in these environments requires a detailed consideration of several factors. One critical aspect is predicting the movements of other road users to anticipate their actions and ensure safety. Additionally, understanding and responding to traffic flow dynamics is essential for smooth integration into real-world conditions. Adhering to traffic regulations also plays a vital role, as autonomous systems must navigate complex scenarios while complying with legal requirements and ensuring orderly operation.

In emergencies, such as a vehicle collision or road blockage, AVs must quickly assess the situation and take appropriate action. This might involve rerouting, slowing down, or even coming to a complete stop. Often, the vehicle must make these decisions autonomously, requiring highly complex and reliable decision-making processes.

Modeling behavior in adverse weather conditions requires realistic simulation environments to accurately replicate the effects of rain, snow, fog, and ice on sensors and vehicle control systems. This involves modeling how various weather conditions influence the performance of cameras, radar, and LiDAR, which are critical for autonomous navigation. Simulations also focus on road surface conditions, such as icy, snowy, or wet terrain, to fine-tune algorithms that enhance vehicle stability and grip. Additionally, they examine how environmental factors, like road signs and lane markings, become obscured under challenging weather conditions, testing the vehicle's ability to interpret these signals accurately. Integrating data from multiple sensors is another crucial element, ensuring robust decision-making even when individual systems are compromised by adverse conditions.

Emergency scenarios require autonomous vehicles to make rapid and precise decisions to ensure safety. In such situations, the ability to detect and avoid obstacles, such as debris or disabled vehicles, is crucial. Vehicles must also be capable of swerving to avoid collisions with out-of-control vehicles, taking into account physical constraints like braking distance and turning radius. Additionally, leveraging V2X communication allows vehicles to receive real-time updates from nearby vehicles, traffic signals, and emergency services, enabling informed and timely responses to evolving situations.

Some emergencies pose ethical dilemmas, requiring the AV to choose between multiple undesirable outcomes. For instance, in an unavoidable collision, should the vehicle prioritize the safety of passengers or pedestrians? Simulation models incorporating ethical decision-making algorithms help test how AVs balance safety, legal liability, and societal values.

Summarizing the aforementioned, it should be stated that modeling the behavior of autonomous vehicles under challenging road conditions is essential for their safe and reliable integration into daily life. Adverse weather and emergency situations present significant challenges that demand sophisticated simulation models. By developing precise simulations that replicate sensor performance, road conditions, and decision-making processes, AV developers can enhance the technology to ensure these vehicles can operate effectively in complex real-world environments. As advancements in simulation accuracy continue, we move closer to a future where AVs can safely and efficiently handle any condition.

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Koshalkovskyi M.V.

THE FUTURE OF INTERNAL COMBUSTION ENGINES

Language Advisor – Senior Lecturer Ivanova I.L.

For over a hundred years, internal combustion engines (ICEs) have powered cars, trucks, planes, and industrial equipment, forming the backbone of modern society. However, as we face a global shift toward sustainability and new technologies emerge, the role of ICEs in our future becomes a topic of extensive debate. While some argue that electric vehicles (EVs) are the way forward, the ICE is not necessarily on the path to disappearance. The future of internal combustion engines will likely be shaped by regulatory policies, technological advancements, and evolving consumer demands.

The environmental impact of ICEs is perhaps the most significant driver of change. Vehicles with traditional combustion engines rely on gasoline and diesel, non-renewable fossil fuels that release CO_2 and other pollutants when burned. This contributes heavily to air pollution and global warming, prompting governments worldwide to enact stricter emissions regulations.

In the European Union, emissions standards are tightening yearly, and the EU has announced plans to ban the sale of new gasoline and diesel vehicles by 2035. Similarly, California, a state known for its rigorous environmental policies, intends to halt the sale of new internal combustion vehicles by 2035, with other states following suit. These legal restrictions are a powerful motivator for car manufacturers to research and develop alternative technologies, notably electric and hybrid vehicles.

Despite regulatory pressure, the ICE is far from obsolete. Advances in technology are making ICEs cleaner and more fuel-efficient. Innovations like turbocharging, direct fuel injection, and start-stop technology have significantly improved fuel economy. New forms of lightweight materials and more aerodynamic designs have also contributed to reducing the emissions of ICE vehicles.

Hybrid engines, which combine electric and internal combustion power, have made an impact by reducing fuel consumption and emissions. This technology has bridged the gap between traditional ICE vehicles and fully electric vehicles, allowing drivers to rely on electric power in city driving or low-emission zones while still using the combustion engine for long-distance travel. Plug-in hybrids take this even further, enabling cars to travel greater distances on electric power before switching to ICE. For many, hybrids represent a transitional step, allowing people to experience electric power without the limitations of battery-only range.

To make ICEs compatible with sustainability goals, researchers are exploring alternative fuels like biofuels, synthetic fuels, and hydrogen. Biofuels are derived from renewable biological sources such as plants or waste and offer a significant reduction in CO_2 emissions compared to traditional fossil fuels. Synthetic fuels, on the other hand, are manufactured through processes that capture CO_2 directly from the atmosphere, making them potentially carbon-neutral.

Hydrogen has also gained attention as a possible alternative for ICEs. Engines powered by hydrogen combust it to produce only water as a byproduct, thus eliminating harmful emissions. This could be particularly promising for heavy industries, aviation, and long-haul transportation, where batteries remain less practical due to weight and charging limitations. Hydrogen combustion engines, however, require infrastructure development to store and transport hydrogen fuel, which remains one of the biggest obstacles to widespread adoption.

Electric vehicles have rapidly become the main alternative to ICE vehicles, especially with major automakers like Tesla, Volkswagen, and General Motors committing heavily to electric lineups. EVs produce no tailpipe emissions and are increasingly seen as the future of personal and light-duty transportation. Technological improvements in batteries, including advances in lithium-ion technology and new types of solid-state batteries, have led to EVs with longer ranges and shorter charging times.

However, the transition to EVs is not without its hurdles. Building a widespread, reliable charging network is a slow and expensive process. While urban areas in developed countries are seeing fast expansion of charging stations, rural and less populated areas still face limited access. Additionally, the high cost and limited availability of raw materials like lithium, cobalt, and nickel required for batteries pose further challenges.

Another often overlooked aspect is the need for stable, renewable energy sources to make EVs truly sustainable. Charging millions of EVs will place a heavy load on electricity grids, especially during peak hours. Without sufficient renewable energy, EVs risk merely shifting emissions from tailpipes to power plants.

Beyond personal transportation, ICE technology will likely continue to play a significant role in heavier industries. While smaller vehicles are more adaptable to electric or hybrid power, sectors like long-haul trucking, aviation, shipping, and construction rely on high power and range that current battery technology cannot yet provide. Batteries for such applications would need to be prohibitively large and heavy, making full electrification less feasible.

Hydrogen, biofuels, and other alternative fuels for ICEs could offer a solution, making it possible for industries to transition to cleaner combustion without compromising performance. Companies are also exploring modular hybrid systems that combine combustion engines with electric motors to provide additional torque when necessary while reducing emissions. For instance, construction vehicles might operate in hybrid mode in urban areas but switch to ICE for high-intensity tasks in rural or off-grid locations.

The shift away from ICEs has implications for jobs and the economy. The production of EVs requires fewer moving parts than ICE vehicles, which could impact jobs in manufacturing, maintenance, and supply chains tied to ICEs. To mitigate this, industries will need to invest in retraining workers and adapting their supply chains to support electric and hybrid vehicle production.

Consumers, too, are a critical part of this transition. While early adopters of EVs are often motivated by environmental concerns or technological interest, the general population’s shift to electric depends on affordability, range, and convenience. Many consumers still find ICE vehicles more affordable and familiar, especially in areas lacking charging infrastructure. As governments continue to incentivize EVs and support EV infrastructure, consumer habits are expected to evolve, but the transition will take time.

To conclude, it should be pointed out that the future of ICE technology is unlikely to be an abrupt end but rather a redefined role in a changing energy landscape. As the world gradually shifts toward a sustainable, low-carbon future, ICEs are expected to adapt, playing a niche role in applications where electrification remains impractical. The development of hybrid systems, clean fuels, and hydrogen combustion engines can extend the relevance of ICE technology in a way that meets both economic and environmental goals.

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Kotenko A.D

STUDY OF EXISTING APPROACHES TO AUTOMATING THE DETERMINATION OF THE COST OF CONSTRUCTION WORK

Language Advisor – Asst.Prof. Vorobyova S.V.

The formation of the cost of any product, work or service involves taking into account the costs of its creation, the amount of profit to be received after the sale of the product (work or service) and the payment of all necessary taxes. Therefore, expenses usually account for the largest share of the cost. The sequence of cost formation in the road sector is regulated by the relevant normative and regulatory documents. In the process of road production, costs are incurred in various production areas that contain costs of different economic content, depending on the nature of the work, technology and labor organization. Therefore, the costs of performing works vary in their quantitative and qualitative composition not only at enterprises of different industries, but also in the same industry.

In the road sector, the process of road works cost formation is currently determined in accordance with the following: guidelines for determining the cost of construction. Taking into account amendments No. 1, 2, 3, 4 [1]; rules for determining the cost of works on current repair and operational maintenance [2]; methodology for determining road works and services to determine the cost of new construction, reconstruction, repair and operational maintenance of public roads [3] and others.

To generate an estimated cost [1-3], the following steps must be taken, which will result in the preparation of a certain type of document.

1. Determination of direct costs.
2. Determination of general production costs.

3. Determination of the estimated cost of the road works object.
4. Determination of the estimated cost of all road works objects.
5. Determination of the estimated cost of all road works objects..
6. Determination of costs for the construction and dismantling of temporary buildings and structures.
7. Determination of additional costs associated with the performance of work in summer and winter.
8. Determination of estimated profit.
9. Determination of administrative expenses.
10. Determination of risk coverage costs.
11. Determination of funds to cover costs associated with inflationary processes.
12. Determination of the costs of maintaining the customer service, other possible costs.
13. Determination of value added tax.
14. Determination of the estimated cost..

Determination of the cost of construction works consists in determining the costs of the works by drawing up a cost estimate of labor, material and technical resources for certain types of works, local estimates for certain types of works and a list of resources to them, which summarize the costs of labor, material and technical works for a certain type of works. These documents are the primary ones in the formation of road works cost. They are compiled in the current level of prices for labor and material and technical resources based on a large number of existing regulatory literature: resource element estimate norms of Ukraine; sectoral resource element estimate norms; resource element estimate norms at the organization level;

relevant instructions for the use of resource element estimate norms; resource estimate norms for the operation of construction machines and mechanisms; current prices for materials, products and structures; current prices for machine hours; current cost of a man-hour for the respective type of work.

Moreover, these regulatory documents are further divided by the type of work performed and other criteria. And current prices are constantly changing in accordance with the state of the economy, which must be constantly monitored in three areas at once: labor, material and technical resources. And while the updated current prices for labor and technical resources are provided by the relevant organizations responsible for this, the prices for material resources must be adjusted on their own based on the current market prices for materials in the relevant region of the country. Thus, it can be concluded that the process of road works costing is not only responsible, but also rather cumbersome, dynamic and labor-intensive. As a result, existing approaches to automation are used to determine the cost of road works and prepare investment estimate documentation, since automation of this process can significantly save time and resources, increase the accuracy and objectivity of calculations [4].

As a result of the research, the author has identified three main approaches to automating the determination of the cost of construction works (Figure 1).

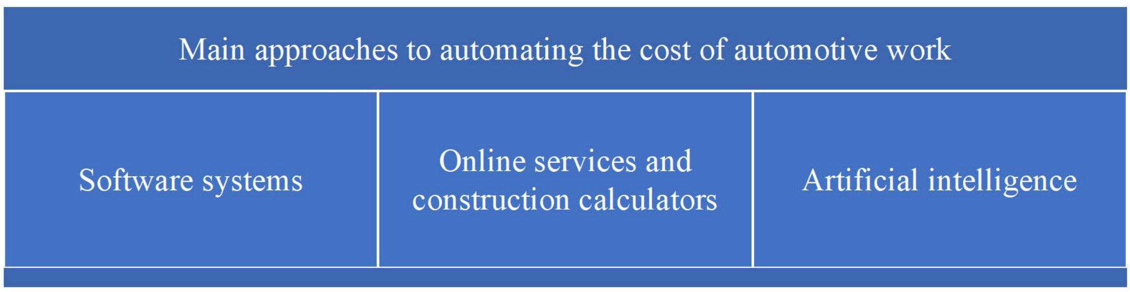

Figure 1 - The main approaches to automating the determination of construction costs

It should be noted that each approach to automating cost estimates has different capabilities.

1) Software systems are programs used to create digital models of buildings that automate the process of determining the cost by analyzing the volume of materials, labor hours, and other factors [5].

- Calculation of the cost of materials, works and machines. They include: creating estimates in various formats; storing and maintaining a price database; and automatically updating price information.

2) Online services - the approach is to use information technology and the Internet to collect data on the progress of construction work in real time. This allows to automatically estimate the cost of work based on up-to-date information on the resources used, labor intensity and other factors [5].

3) Artificial intelligence is also another promising approach. Algorithms can be trained on historical labor cost data, such as material prices, labor hours, and regional differences, to predict future project costs. This approach reduces the time required to estimate labor costs and avoids human error in calculations. However, it is important to have enough high-quality data to train the algorithm and update it regularly to ensure that the results are up-to-date.

Despite its useful functionality, each of the methodological approaches under consideration has a number of advantages and disadvantages (Table 1).

Table 1 - Advantages and disadvantages of automation methods

Method of automation of estimate work	Advantages	Disadvantages
Software systems	- Calculating the cost of materials, work, and machinery; - Creating estimates in various formats; - Storage and maintenance of a price database; - Automatic updating of price information.	- High cost of software; - The need for staff training; - Possibility of errors in databases.
Online services and calculators	- Accessibility from any location; - Does not require significant investments.	- Dependence on an internet connection - Possible data security issues - Limited functionality compared to software systems
Artificial intelligence	-High forecasting accuracy -The ability to take into account many factors - Automation of routine tasks	- High cost of development and implementation - The need for qualified personnel - Possible ethical issues

In general, the approaches under consideration have general similarities in their operation. Basically, they are fast, which allows you to spend less time compared to non-automated work. Accuracy in calculations is also a common feature. We shouldn't forget about the ability to predict risks and inaccuracies. But there are also common disadvantages in these environments. Constant program updates in these methods can have a negative impact on users.

Conclusions. Automation of construction cost estimation offers great potential for improving the efficiency and accuracy of this process. There are many different approaches to automation, the main ones being the use of software, artificial intelligence and machine learning. Each of these approaches has advantages and disadvantages, so it is important to choose the one that best suits the specific needs and capabilities of the construction company. Also, analyzing each of these methods, one can understand that in real time, software systems will be more efficient due to their large database, flexible functionality, and widespread use among construction companies. Online services and calculators are more popular for quick and small calculations, and the use of artificial intelligence has not yet become so widespread that it is possible to predict the quality of such a method. In the future, the author would like to see a combination of such methods in a so-called “hybrid”. Artificial intelligence will be able to develop online services and come closer to the success of software systems or increase the efficiency of using software systems. Today, the most effective software systems in the road sector are Estimates8 and AVK-5.

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Kovtun V.V.

REVOLUTION ON WHEELS: THE UK'S PATH TO AUTOMOTIVE SUSTAINABILITY

Language Advisor – Senior Lecturer Ivanova I.L.

In recent years, the UK's automotive industry has been undergoing a true technological revolution. In response to tightening environmental standards and the global trend of reducing carbon footprints, British car manufacturers are actively introducing innovations in engine technology. From hybrid units to fully electric motors — the new wave of technology promises to change the rules of the game in the global car market.

New Direction: Electrification and Hybridization. One of the key trends has been the increased focus on electric and hybrid engines. British car manufacturers such as Jaguar Land Rover, Rolls-Royce, and emerging startups are actively developing electric transport. Jaguar has already announced plans to fully transition to electric vehicle production by 2025. Their new electric motors promise to be not only powerful but also energy-efficient, allowing drivers to travel up to 500 km on a single charge.

Moreover, hybrid technology is experiencing a renaissance. Land Rover is actively releasing hybrid versions of its iconic SUVs. The latest PHEV (Plug-in Hybrid Electric Vehicle) engines combine the capabilities of an electric motor with a traditional internal combustion engine (ICE), significantly reducing CO2 emissions and increasing fuel efficiency.

Hydrogen Technology. Developments in hydrogen engine technology also deserve special attention. Companies like Riversimple are promoting the idea of environmentally friendly transport based on hydrogen fuel cells. Hydrogen cars emit only water as exhaust and can be refueled in a matter of minutes. The UK government supports the development of hydrogen infrastructure, opening up great prospects for this direction.

Innovations in Traditional Internal Combustion Engines. Despite the general trend toward electrification, internal combustion engines (ICE) have not been completely abandoned. Engineers in the UK are working on improving the efficiency of ICEs through the use of new materials and fuel combustion technologies. For instance, Cosworth is actively experimenting with hybrid systems based on ICEs, which allows for reduced fuel consumption and emissions.

Key Players and Their Innovation:

- Jaguar Land Rover (transitioning to fully electric models by 2025);
- Rolls-Royce (introducing of electric engines for the premium class);
- Riversimple (promoting of hydrogen cars and creation of infrastructure);
- Cosworth (developing hybrid systems for sports and mass-market vehicles)

Economic Impact and Government Support. The UK government actively supports the transition to green technologies. As part of the Green Industrial Plan, billions of pounds have been allocated to finance research and development projects in clean engine technology. The goal is to make the UK a world leader in the production of "green" vehicles.

Moreover, the shift to electric and hybrid engines contributes to the creation of new jobs in R&D (research and development) and battery production. The UK is expected to become a major exporter of innovative engines and batteries.

Challenges and Obstacles. Despite all the advantages, the development of new engines is associated with a number of challenges. The main problems include:

- high production costs (this is especially true for hydrogen technology);

- need for infrastructure development (building charging stations and hydrogen refueling points requires significant investment);

- shortage of raw materials (the lack of rare earth materials for battery production could slow progress).

Based on the above, it can be concluded that the new engines for cars from the UK are not just technological innovations, they are a challenge for the entire global automotive industry. British companies aim to be at the forefront of this revolution, introducing hybrid, electric, and hydrogen solutions. With government support and growing demand for environmentally friendly transport, the UK has every chance of becoming a world center for advanced automotive technology. Whichever path companies choose — electricity, hydrogen, or hybrids — one thing is clear: the UK's automotive industry is on the brink of a new era.

Technological Breakthroughs on the Horizon. The future of engine development in the UK is not limited to current trends. New projects aimed at enhancing engine performance are already underway. One promising avenue is the development of solid-state batteries, which promise greater energy density, faster charging times, and improved safety compared to traditional lithium-ion batteries. Companies like Britishvolt are at the forefront of this technological race, building large-scale battery production facilities to support the growing demand for electric vehicles.

Another breakthrough technology is the use of advanced AI-driven predictive maintenance systems for engines. By using AI algorithms to detect potential issues before they occur, British automakers aim to reduce maintenance costs and increase vehicle lifespan. This predictive approach could revolutionize fleet management for both personal and commercial vehicles.

The Role of Startups and Research Institutions. While major players like Jaguar Land Rover and Rolls-Royce lead the charge, startups and research institutions are playing a crucial role in innovation. Newcomers like Arrival are developing ultra-efficient electric delivery vans, while academic institutions such as Imperial College London are researching new battery chemistries and materials that could redefine the industry's future.

Universities and research hubs collaborate with private companies to accelerate innovation. Government-funded initiatives like the Faraday Institution focus on energy storage solutions, aiming to create groundbreaking battery technologies that will benefit both the UK and the wider world.

Consumer Perception and Adoption. Public perception of new engine technology is another factor driving industry change. As consumers become more environmentally conscious, the demand for electric and hybrid vehicles is on the rise. In response, British automakers are focusing on producing not only efficient engines but also vehicles that deliver a superior user experience. From intuitive infotainment systems to enhanced safety features, modern British vehicles are designed to appeal to a broad range of consumers.

Moreover, the shift in consumer attitudes is being driven by government incentives. Subsidies, tax breaks, and exemptions from congestion charges make electric vehicles more attractive to buyers. The UK government's goal to ban the sale of new petrol and diesel cars by 2030 adds further impetus to the shift toward cleaner engine technologies.

Sustainability and Ethical Considerations. Sustainability is at the heart of the UK's automotive revolution. Companies are not only reducing vehicle emissions but also rethinking their entire supply chains. Ethical sourcing of materials like lithium, cobalt, and nickel is becoming a priority. Car manufacturers are seeking suppliers who adhere to sustainable mining practices and promote worker welfare. Recycling initiatives for old batteries are also being expanded, reducing waste and supporting a circular economy.

Future Outlook. The future of UK engine development holds exciting possibilities. Advancements in battery technology, hydrogen infrastructure, and AI-driven maintenance are expected to converge, creating a new generation of vehicles that are cleaner, smarter, and more efficient. The UK's automotive industry is on track to become a global leader in green vehicle technology, setting an example for other countries to follow.

.To conclude, it should be noted that the UK automotive industry is spearheading a revolution in sustainable transportation, driven by advancements in electrification, hydrogen technology, and hybrid systems. Supported by government initiatives and substantial investments, the sector is fostering innovation, creating jobs, and reducing environmental impact. Major manufacturers, startups, and research institutions are developing cutting-edge solutions like solid-state batteries and AI-driven maintenance systems. Despite challenges such as high costs and infrastructure needs, the UK is making strides toward a greener future. Positioned as a leader in clean mobility, the UK is paving the way for a sustainable, efficient, and technologically advanced global automotive industry.

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Kysliak M. S.

DEVELOPING EFFECTIVE LOGISTICS STRATEGIES FOR BUSINESS COMPETITIVENESS

Language Advisor – Asst. Prof. Chevychelova O. O.

The modern market clearly demonstrates the significant role enterprises play in ensuring the stable functioning of the economy. The success, dynamic development, and competitiveness of contemporary companies are largely determined by the quality of their logistics processes' organization and management.

Logistics is a process aimed at planning and implementing the optimal transportation and storage of products, from the point of production to the end consumer. The primary goal of logistics is to deliver necessary goods to customers on time and at minimal cost (Rudkivskyi, 2018).

At the strategic level of logistics management, goals, objectives, and development directions are formulated to align with the enterprise's corporate strategy. The logistics strategy, as a part of overall strategic planning, determines the methods for achieving corporate goals through logistics management mechanisms.

The main objectives of the logistics strategy include optimizing inventories, reducing transportation and storage times, increasing customer service levels, and minimizing total costs within the logistics chain (Vodolazhska, 2021, p. 41-60).

An analysis of the works by Ukrainian and foreign scholars (O. Rudkivskyi, N. Ilchenko, V. Redko, J. Stock, D. Lambert, and others) highlights the high relevance of developing and implementing logistics strategies in production activities. Researchers focus on various aspects of this process, offering different approaches to classifying logistics strategies.

Types of logistics strategies include "thin" strategy (cost orientation), which focuses on minimizing resource use, such as human, material, and time; "dynamic" strategy (service orientation), which aims to ensure high service quality and rapid response to changes in customer requirements; productivity strategy (O. Rudkivskyi), which combines cost reduction with maintaining service levels, thus expanding customer choice; and strategic alliances (N. Ilchenko), which focuses on long-term cooperation between suppliers and consumers to enhance supply chain efficiency.

Ukrainian scholar V. Redko suggests categorizing logistics strategies into areas that address key tasks, such as integration of functions and processes, consolidation of transport, warehouse, and inventory operations, reduction of inventories, shortening order fulfilment cycles, service differentiation, and cooperation between suppliers and consumers.

Developing a logistics strategy involves defining the logistics mission and goals, conducting an analysis of the logistics environment, auditing existing logistics processes, and making strategic decisions regarding development. It is essential to consider both external factors (competition, technological development, environmental constraints) and internal factors (organization level, competencies, use of modern information technologies, infrastructure) when developing logistics strategies.

In addition, businesses must account for their unique features, customer needs, and long-term plans during this process.

Modern economic development places new demands on enterprises, particularly in logistics management, which plays a vital role in ensuring their competitiveness. Effective logistics integrates supply, production, storage, and sales processes aimed at meeting customer needs with minimal resource consumption.

A significant aspect of logistics today is digitalization, which transforms management approaches. Technologies like Big Data, IoT, and AI enable the analysis of large datasets, demand forecasting, inventory management automation, and delivery route optimization. These tools offer enterprises new opportunities, improving logistics efficiency.

At the same time, environmental considerations are increasingly important. Enterprises are implementing measures to reduce CO_2 emissions, use eco-friendly transport, and optimize logistics operations. The concept of "green logistics" is gaining strategic importance, allowing businesses to meet legal requirements and build a positive consumer image. Globalization also impacts logistics strategies, as integration into international supply chains opens new markets while increasing the risks of global crises.

Flexibility and adaptability are essential elements of logistics strategies, enabling enterprises to quickly respond to changes in the external environment. Developing alternative routes, diversifying suppliers, and building contingency plans are crucial components of successful companies' strategies. Additionally, customer orientation is increasingly emphasized, ensuring high service quality, real-time information availability, and consideration of individual customer needs. This strengthens consumer trust and maintains competitive advantage.

Automation and robotics are other significant trends affecting logistics strategies. The use of robots in warehouse operations, autonomous transport, and drones for delivery increases speed, accuracy, and efficiency. Investments in such technologies are becoming strategically important for enterprises seeking to remain innovative and stay ahead of competitors.

Thus, the formation of logistics strategies in modern conditions is based on analysing internal and external factors, utilizing modern technologies, and implementing innovative approaches. Effective logistics not only reduces costs and increases efficiency but also helps enterprises adapt to changes, achieve long-term goals, and meet customer needs in a dynamic environment.

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Lopata A.O.

FIVE MAJOR BENEFITS OF ELECTRIC FORKLIFTS

Language Advisor – Asst. Mykytenko I. V.

These past few years, we have noticed a change in the type of energy companies choose to fuel their material handling machinery. A lot of operations are replacing their internal combustion forklifts with electric ones. Industrial companies seem to embrace electric energy solutions, and why wouldn’t they? Electric trucks have become highly efficient, powerful and performant. They can easily handle heavy loads, are versatile, and they give your operation the opportunity to organize your material handling in an environmentally conscious way (if you opt for green electricity). Let’s zoom in on some of the benefits of electric forklifts and explain them in more detail.

Environmentally conscious

Electric forklifts produce zero emissions. So, if you choose green electricity, you can dramatically reduce your carbon footprint. Even after a truck's best years, its environmental impact can be minimized; lead-acid batteries are mainly made of lead, which can be recycled, and lithium-ion batteries are the best in the electric class because they are 30% more energy efficient and last three to four times longer than lead-acid batteries. Electric forklifts are ideal if a country has decided to restrict or ban the use of forklifts with an internal combustion engine. But "no emissions" means not only the benefits of the external environment, it is also possible to create a healthier and cost-effective working environment in your warehouse:

- no more exhaust fumes or other toxic gasses
- no need for ventilation and thus lower heating costs
- lower energy costs as these energy-efficient trucks only consume the energy they truly need

Designed for safe operation

Thanks to technological evolution, electric forklifts have an improved regenerative braking system for increased safety. If the operator takes his foot off the gas pedal, the forklift stops instantly. In electric forklifts, the software is optimized so that all types of operators can control their trucks quickly and accurately. All trucks are equipped with SAS (Active Stability System), which keeps the truck stable and the warehouse safe.

Quieter operations

Electric forklifts are very quiet, especially compared to internal combustion trucks! There are two types of noise you can hear when driving an electric forklift: tires screeching on the floor and an alarm when you reverse. The reduction in the warehouse will make it easier for other operators and pedestrians to hear other important sounds on the jobsite, such as other equipment beeping, a truck honking to warn, or a colleague announcing the next urgent task.

A quiet forklift promotes workplace safety and communication, as well as operator health. Loud sounds can be distracting; they will cause headaches, stress and fatigue for operators. Prolonged exposure to noise can even lead to hearing damage or loss. Electric forklifts protect the ears and health of warehouse workers.

Reduction of operating costs

- lower O&M costs as they have fewer parts (eg no coolers or engine oil) and require less maintenance overall
- installation of charging stations, but electricity is much cheaper than fuel

- more space, as lithium-ion trucks do not require a separate, ventilated charging room
- more time during which the truck can be actively used (because they require less service and maintenance)
- I_Site fleet management system that increases productivity and ROI with fleet data and helps save even more budget

Great for all types of applications

Ideal for navigation in narrow corridors and tight spaces; they have a small chassis and a compact turning radius, improving maneuverability. In this way, electric forklifts can really maximize space and efficiency while keeping power in a complex warehouse.

Electric forklifts are durable and suitable for both indoor and outdoor use, unlike engine powered machines. Long gone are the days when electric material handling solutions were less powerful or less sustainable than their diesel or LPG counterparts. In fact, electric forklifts can handle very heavy loads and almost all types of materials.

So, now we know that electric forklifts have many advantages. Not only are they more energy efficient and environmentally friendly, they can also save you a lot of money and space. Regardless of the task, now is the perfect time to switch to all-electric forklifts.

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Malyi V. M.

RESEARCH OF CONTROLLABILITY OF A PASSENGER CAR WITH A TRAILER DURING A MANEUVER WITH A SHARP LANE CHANGE

Scientific Advisor – DSc (Engineering), Prof. Leontiev D. M.
Language Advisor – CandSc (Education), Assoc. Prof. Borzenko O. P.

The modern development of transport systems and increased population mobility lead to an increase in the popularity of using passenger cars with trailers. They are widely used in both the private and commercial sectors (Dižo, 2023).

The controllability of a car with a trailer is an important operational property that determines its ability to maintain a trajectory and adequately respond to the driver's actions in different conditions. Controllability has a direct impact on road safety, but the "car-trailer" system has complex dynamics (He Yuping, 2013), which significantly complicates the evaluation of this property in real conditions.

In our research, we will rely on the international standards ISO 3888-1 (ISO, 2018) and ISO 3888-2 (ISO, 2011), which regulate standard scenarios for assessing the controllability of cars weighing up to 3.5 tons, regardless of their configuration. Table 1 shows the main parameters of these tests and the criteria for evaluation.

Table 1. – Main test parameters according to ISO 3888

Standard	**Test scenario**	**Evaluation criteria**
ISO 3888-1	Double maneuver	Accuracy of returning to the trajectory, trailer stability.
ISO 3888-2	Avoiding an obstacle	System stability, movement trajectory, no skidding.

As part of the research, an analysis of the kinematics and dynamics of turning a two-link passenger road train was carried out and a mathematical model in the MATLAB/Simulink software package was built.

In kinematic research, an important step is to determine the angles between the absolute velocity vector and the longitudinal axis of each link of the road train. In a generalized form, the values of these angles can be calculated using the following relationship:

$$\begin{bmatrix} \Xi_1 \\ \Xi_2 \end{bmatrix} = \begin{bmatrix} \tan^{-1}\left(\dfrac{V_{y1} + l_1 \cdot \omega_1}{V_{x1} + k_1 \cdot \omega_1}\right) \\ \tan^{-1}\left(\dfrac{V_{y2} + l_2 \cdot \omega_2}{V_{x2} + k_2 \cdot \omega_2}\right) \end{bmatrix},$$

where:

- Ξ_1, Ξ_2 – angle value for car and trailer respectively;
- $V_{x_1}, V_{y_1}, V_{x_2}, V_{y_2}$ – projections of the absolute velocity of the mass center of the car and trailer respectively in their local coordinate system;
- ω_1, ω_1 – angular velocity of the car and trailer respectively;
- l_1, k_1, l_2, k_2 – projections of the distances of the velocity vector to the turning center of the car and trailer, respectively.

In dynamic analysis, the main forces acting on the car and trailer during movement should be taken into account. In our case, the following factors were considered:

- Weight of the car and trailer, load distribution.
- Traction forces and rolling resistance, values of the deflection angles.
- Inertia forces arising during maneuvering.

To form a mathematical model, the Newton-Euler equation was used, adapted to the interaction of two bodies (car and trailer).

To carry out road test simulations, we use the MATLAB/Simulink software environment, which allows us to integrate kinematic and dynamic aspects in one platform.

The simulation of the road train movement was carried out under specified boundary conditions regulated by ISO 3888 standards.

The results of the simulation test according to ISO 3888-1 are shown in Figure 1.

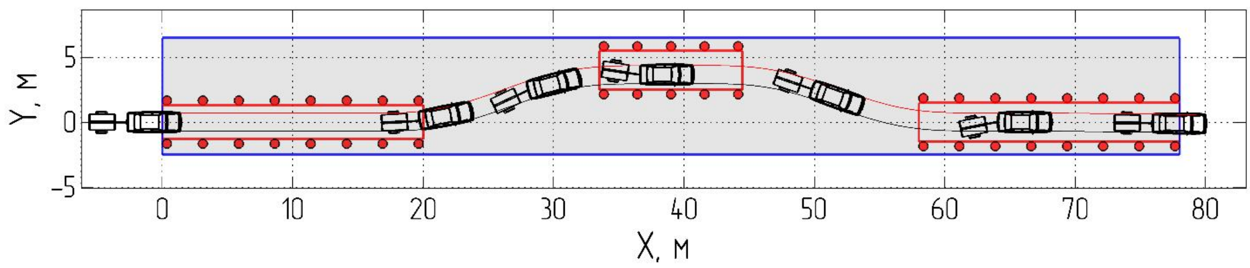

Figure 1. – Test result according to ISO 3888-1 at a speed of 50 km/h

The results of the simulation test according to ISO 3888-2 are shown in Figure 2.

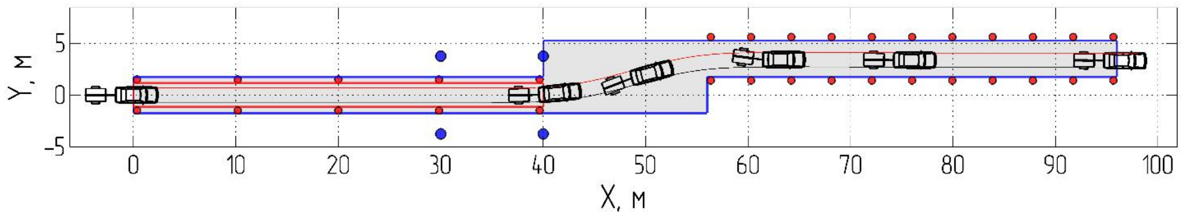

Figure 2. – Test result according to ISO 3888-2 at a speed of 50 km/h

Research of the controllability of a car with a trailer according to ISO 3888 standard scenarios made it possible to evaluate its behavior in critical conditions and identify ways to improve safety. Improving the design characteristics of trailers and adapting active safety systems should become a priority for vehicle and trailer manufacturers.

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Minchenko A.S.

ENVIRONMENTAL IMPACT OF ROAD TRAFFIC: STRATEGIES FOR MITIGATION

Language Advisor – Lecturer Lukianenko N.M.

As urban areas expand and the global population continues to rise, road traffic has become a defining feature of modern life. However, this convenience comes with significant environmental costs. The reliance on motor vehicles contributes to various forms of pollution, including air and noise pollution, while also playing a crucial role in climate change. According to the World Health Organization, outdoor air pollution is responsible for approximately 4.2 million premature deaths each year, with traffic emissions being a major contributor (WHO, 2021). The gases emitted by vehicles, particularly carbon dioxide (CO2), nitrogen oxides (Nox), and particulate matter (PM), have far-reaching implications for public health and the environment.

Air quality has deteriorated in many urban areas due to increasing vehicle emissions, leading to severe health issues such as respiratory diseases, cardiovascular problems, and even premature mortality (Jones, 2022). Furthermore, as road traffic intensifies, noise pollution becomes an overlooked yet critical issue. Chronic exposure to high levels of traffic noise has been linked to stress, sleep disturbances, and a decline in overall quality of life (Miller, 2023). These factors create an urgent need for comprehensive strategies to mitigate the environmental impacts of road traffic.

In addition to health concerns, road traffic contributes significantly to greenhouse gas emissions, which are the primary drivers of climate change. The transportation sector, particularly road vehicles, accounts for nearly a quarter of total greenhouse gas emissions in many countries (Smith, 2023). As global temperatures rise, the consequences become increasingly severe, affecting weather patterns, sea levels, and biodiversity. Moreover, the expansion of road networks often leads to habitat destruction and fragmentation, disrupting ecosystems and threatening wildlife populations (Roberts, 2022).

This paper aims to explore the multifaceted environmental consequences of road traffic while offering strategies for mitigation. By examining the impact of public transportation, active transportation, electric vehicles, congestion pricing, and vehicle efficiency standards, we can outline a pathway toward more sustainable urban mobility. Ultimately, addressing the environmental impacts of road traffic is not just a matter of compliance or policy; it is essential for protecting public health and fostering a sustainable future for our cities and planet.

Environmental Consequences of Road Traffic.

Air Pollution.

One of the most immediate impacts of road traffic is air pollution. Vehicles emit a range of harmful pollutants, including nitrogen oxides (Nox), particulate matter (PM), carbon monoxide (CO), and volatile organic compounds (VOCs). These emissions contribute to respiratory diseases, cardiovascular problems, and other health issues in urban populations (Jones, 2022). According to the World Health Organization, outdoor air pollution caused by traffic contributes to approximately 4.2 million premature deaths annually worldwide (WHO, 2021).

Greenhouse Gas Emissions.

Road traffic is a major source of carbon dioxide (CO2) emissions, a primary greenhouse gas driving climate change. In many countries, transportation accounts for nearly a quarter of total greenhouse gas emissions, with road vehicles being the largest contributors within this sector (Smith, 2023). As global temperatures rise, the effects of climate change—such as extreme weather events and sea-level rise—pose significant risks to ecosystems and human populations.

Noise Pollution.

Traffic noise is another environmental consequence that affects urban areas. It can lead to various health problems, including stress, sleep disturbances, and reduced quality of life. Long-term exposure to high noise levels has been linked to increased risks of heart disease and cognitive impairment (Miller, 2023).

Habitat Destruction and Fragmentation.

The expansion of road networks often leads to habitat destruction and fragmentation, disrupting ecosystems and threatening wildlife. Roads can create barriers that hinder animal movement, contribute to habitat loss, and increase mortality rates among wildlife due to vehicle collisions (Roberts, 2022).

Strategies for Mitigation.

Promoting Public Transportation.

Investing in and promoting public transportation can significantly reduce the number of vehicles on the road, thus decreasing traffic emissions. Public transport systems, such as buses, trains, and subways, are generally more efficient than individual car travel, resulting in lower emissions per passenger. Cities that have prioritized public transport, like Amsterdam and Tokyo, have seen reductions in traffic congestion and pollution levels (Johnson, 2021).

Encouraging Active Transportation.

Encouraging walking and cycling is another effective strategy to mitigate the environmental impact of road traffic. Developing pedestrian-friendly infrastructure, such as sidewalks, bike lanes, and secure bike parking, can promote active transportation. Studies show that cities with robust cycling infrastructure experience lower traffic-related emissions and improved air quality (Miller, 2023).

Adopting Electric Vehicles (Evs).

Transitioning to electric vehicles (Evs) can significantly reduce greenhouse gas emissions from road traffic. While the manufacturing of Evs has an environmental impact, their operation produces no tailpipe emissions. Government incentives for EV adoption, alongside investments in charging infrastructure, can accelerate this transition (Smith, 2023).

Implementing Congestion Pricing.

Congestion pricing is a strategy that charges drivers a fee to enter high-traffic areas during peak hours. This approach can reduce traffic volumes, encourage the use of public transport, and lower emissions. Cities like London and Singapore have successfully implemented congestion pricing, resulting in improved traffic flow and reduced pollution levels (Johnson, 2021).

Enhancing Vehicle Efficiency Standards.

Strengthening fuel economy standards for new vehicles can lead to significant reductions in emissions. Governments can implement stricter regulations to ensure that manufacturers produce more fuel-efficient vehicles. Innovations in automotive technology, such as hybrid engines and lightweight materials, can also contribute to improved efficiency (Roberts, 2022).

The environmental consequences of road traffic are profound and multifaceted, affecting air quality, public health, and climate stability. As urban populations grow and reliance on motor vehicles increases, the urgent need for effective strategies to mitigate these impacts has never been clearer. This paper has highlighted several key areas where interventions can significantly reduce the negative effects of road traffic.

First, promoting public transportation is crucial. By investing in efficient and accessible transit systems, cities can reduce the number of individual vehicles on the road, leading to lower emissions and improved air quality. Public transport not only serves as a more sustainable alternative but also enhances mobility for all, particularly for those without access to private vehicles.

Second, encouraging active transportation—such as walking and cycling—can play a vital role in mitigating traffic-related emissions. By developing pedestrian-friendly infrastructure and safe cycling lanes, cities can foster a culture of active travel. This not only reduces reliance on cars but also promotes public health through increased physical activity.

The transition to electric vehicles (Evs) presents another significant opportunity. As battery technology advances and charging infrastructure expands, Evs can offer a cleaner alternative to traditional fossil fuel-powered vehicles.

Government incentives and public awareness campaigns are essential to facilitate this transition and maximize the environmental benefits.

Implementing congestion pricing is also an effective strategy to manage traffic volume. By charging drivers for entering high-traffic areas during peak times, cities can encourage the use of public transport and reduce overall traffic congestion, leading to decreased emissions. Cities like London and Singapore have demonstrated that such pricing models can successfully improve traffic flow and lower pollution levels.

Finally, enhancing vehicle efficiency standards is critical for reducing emissions from the existing vehicle fleet. Stricter regulations can drive innovation in automotive technology, resulting in cleaner and more efficient vehicles on the roads.

In conclusion, addressing the environmental impacts of road traffic requires a multi-faceted approach that combines policy changes, technological advancements, and public engagement. By prioritizing public transportation, active transportation, electric vehicles, congestion pricing, and improved vehicle efficiency, we can create a more sustainable urban environment. Ultimately, mitigating the environmental consequences of road traffic is not only essential for public health but also vital for ensuring a sustainable future for our cities and the planet.

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Mokhonko R.O.

FREEVALVE TECHNOLOGY GAS DISTRIBUTION MECHANISM

Language Advisor – Asst. Mykytenko I.V.

The gas distribution mechanism is part of the internal combustion engine. The gas distribution mechanism in the internal combustion engine is necessary to set the opening moment of the intake and exhaust valves. This mechanism ensures that the valves open and close at the right times throughout the engine cycle for efficient combustion, optimum power output and fuel economy.

The mechanism consists of a camshaft, which is driven by a crankshaft and controls the intake and exhaust valves. There are several constructions of the gas distribution mechanism. But usually the camshaft lobes push the valves, opening them to allow the air-fuel mixture to enter the combustion chamber, and then close to allow compression and combustion, and open to release the exhaust gases. The valve opening time is carefully calibrated, according to the cycle in each cylinder.

Correct timing is critical, as accurate valve timing improves engine power by ensuring the right amount of air-fuel mixture enters the combustion chamber. Properly timed intake and exhaust cycles maximise fuel burn, helping the engine run more economically. Synchronisation helps improve fuel combustion, reducing exhaust emissions.

In more modern engines, variable valve timing systems dynamically adjust valve timing, for example, VTEC is an automatic valve lift control system in Honda power plants. Allows you to control the filling level of the combustion chambers of the combustible mixture, depending on the load the engine is operating at. As a result, a engine works more economically at low revolutions and provides produces high power at maximum revolutions.

In this paper, we want to look at the FreeValve technology developed by Koenigsegg. FreeValve is used instead of the gas distribution mechanism. This system controls each valve individually, using electronically controlled actuators. This technology allows precise control of valve opening and closing, significantly increasing engine efficiency, increasing power output and reducing fuel consumption.

Let’s take a look at how the FreeValve system works. FreeValve technology uses a combination of pneumatic, hydraulic and electronic components to independently control each engine valve, allowing precise control of valve timing and valve lift. An electrical impulse is applied to the valve solenoid, causing the valve to open. A combination of air and hydraulic pressure 212ptimized212 the opening of the valve, dampening any oscillations. Air and hydraulic pressure also determine how far the valve opens. If no electrical signal is applied to the solenoid, hydraulic pressure causes the valve to close. Unlike traditional engines that use a camshaft to control multiple valves at the same time, the FreeValve design allows each valve to open at a precise time according to the engine speed and load applied to it.

The system works through electro-hydraulic actuators that can open and close the valves without the mechanical constraints of a camshaft. This allows for various operating strategies, including running the engine in different cycles (like the Miller cycle) for improved efficiency, cylinder deactivation for better fuel economy, and 213 ptimized combustion strategies adjusted dynamically based on load.

Advantages of FreeValve include eliminating everything connected to the camshaft assembly, including the timing assembly, gears, chain/belt and cover, reduced manufacturing materials and lower installation costs.

One of the main problems of users of internal combustion engines has always been the breakage of the belt/chain of the gas distribution mechanism, which led to serious damage to the engine and subsequent expensive repairs. This problem is eliminated in the FreeValve engine because it does not have a rotating assembly associated with the valves. If the system that controls the valves fails, the engine simply stops running and the valves remain in the fully closed position. This means there is no risk of bent valves or damaged pistons. According to FreeValve, tests of the valve actuators showed no noticeable wear after hundreds of millions of cycles, giving them the same life expectancy as the current engine.

Although Koenigsegg's FreeValve technology has numerous benefits, such as increased efficiency, increased power and lower emissions, it also has some drawbacks. Namely, a much more complex system that includes more components and more complex electronics. These electronics require periodic maintenance. Also, FreeValve systems requires high-precision equipment, which makes such a system more expensive to manufacture. Difficulty in maintenance and repair, because the FreeValve system is new, and can create maintenance problems. Few service centres will be able to service or repair such systems, as they require special knowledge and equipment.

Overall, the FreeValve is a promising development that has the potential to change the standard design of internal combustion engines, creating the basis for greener, more economical and more powerful vehicles.

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Niemykin V. A.

EVOLUTION AND FUTURE OF AUTOMATIC TRANSMISSION: FROM TECHNICAL BREAKTHROUGH TO INTELLIGENT SYSTEMS

Language Advisor – Senior Lecturer Ivanova I.L.

The automatic transmission (AT) is not just a technological invention, but a true indicator of the progress of the automotive industry. Its history begins with the ambition of engineers to make driving easier and more comfortable. Imagine the early 20th century: roads were just being formed, cars were just beginning to replace carriages, and manual transmissions were a challenge for drivers. Each gear change required a clear sense of timing, technical knowledge and great skill.

The first attempts to automate the process began in 1904, when the Sturtevant brothers created a primitive mechanism that could shift gears without the driver's involvement. However, the design was unreliable, and it was quickly forgotten. It wasn't until the 1920s that Alfred Horner Munroe made his contribution by patenting a box that ran on compressed air. However, this invention did not become widespread due to insufficient power and complexity of production.

The real breakthrough came in 1939, when General Motors launched its legendary Hydra-Matic. It was the first commercially successful automatic transmission that allowed drivers to completely forget about the gear lever. Hydra-Matic was a sensation and influenced the development of the automotive industry. Drivers no longer had to concentrate on shifting gears in city traffic or on steep hills. They could now enjoy driving, leaving the technical processes to the machine.

In the 1950s, the automatic transmission became a symbol of luxury and modernity. American automatic cars were advertised as a technical marvel that made life easier. Imagine a family driving their big Buick on wide American roads without having to worry about shifting gears. It was a true image of well-being at the time.

Europe, however, was initially doubtful about automatic transmissions. They appreciated the control and dynamics provided by the manual. But over time, even European manufacturers recognized the advantages of the automatic. Variants of adapted gearboxes began to appear in sports and premium cars.

Since then, the automatic transmission has evolved along with the automotive industry. Electronic control systems have made it even smarter. It has learnt to adapt to the driver's driving style, assess the road situation and change gears as efficiently as possible. Later, variators and dual-clutch transmissions were introduced, combining the advantages of a classic automatic and a manual.

Today, automatic transmission is an important element of modern transport. It makes driving comfortable, especially in large cities with traffic jams. An automatic transmission reduces driver fatigue, allowing you to focus on the road rather than on gear changes. In addition, in combination with hybrid engines, it helps to reduce emissions, contributing to environmental protection.

The automatic transmission is an example of how technology can change the lives of millions of people. It has evolved from experimental models to high-tech systems that are now the standard for comfort and efficiency. Its history is a story of engineering genius, adaptation to the needs of the times and the desire to make the car an indispensable partner in our daily lives.

Imagining the future, the automatic transmission is likely to become even smarter. Its integration with autonomous driving systems will make it possible to make cars fully self-driving, where a person only chooses a destination and the car does the rest. This proves that the automatic transmission is not just a mechanism, but a whole chapter in the history of technological progress that continues to this day.

The future of the automatic transmission looks extremely promising, as technology is constantly moving forward, opening up new horizons. With the advent of electric and autonomous vehicles, the role of the automatic transmission is changing, but its importance remains key. Electric motors that use a single constant gear require less complex solutions, but even in this case, automation ideas remain relevant.

In the coming decades, the automatic transmission is likely to integrate with other vehicle systems. For example, it will become part of a general network of sensors and artificial intelligence that will analyse the road situation, weather conditions and the driving style of other road users. Imagine a car controlled by the system deciding on its own when to accelerate, when to slow down, and even how to maintain optimal energy levels.

Another important area of development is environmental friendliness. Governments in many countries are already introducing stringent emission standards, and manufacturers are forced to adapt their technologies. The automatic transmissions of the future will become even more efficient, helping to reduce fuel consumption and CO_2 emissions. For example, hybrid cars with automatic transmissions are already using them to switch between internal combustion engines and electric motors.

In addition, gearboxes are likely to become less bulky and simpler in future. This will reduce vehicle weight, which is critical for electric and hybrid vehicles. The development of new materials, such as composites or ultra-light metals, will also contribute to this process.

An interesting trend is the introduction of wireless update technologies. Just like modern smartphones, the automatic transmissions of the future will be able to receive software updates, improving their performance and adapting to new standards. Imagine your car 'learning' new optimization algorithms just by connecting to the Internet.

At the same time, the automatic transmission is not losing its role in premium vehicles. Here, it will continue to evolve in the direction of providing maximum smoothness, shift speed and comfort. For example, sports cars with dual-clutch automatic transmissions provide instant response and optimum control, leaving you feeling completely at one with the car.

In addition, automatic transmissions can play an important role in the development of autonomous transport systems. In a world where autonomous vehicles will become the norm, automatic transmissions will ensure smooth and safe driving by working in tandem with sensors, radars and cameras. Imagine a world where vehicles communicate with each other and choose the best solutions for safe and efficient driving.

Summarizing the above, it should be stated that the automatic transmission is not just a part of the car, it is a technology that connects the past, present and future. It evolves with society and technology, continuing to improve our driving experience. In the future, it is likely to become even smarter, greener and more integrated with other technologies, while remaining a symbol of comfort and innovation.

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Sakhno V.O.

HISTORY OF THE DEVELOPMENT OF TRANSPORT TECHNOLOGIES

Language Advisor – Senior Lecturer Ivanova I.L.

Transport is a system of means and methods used to move people, cargo, and products from one place to another. Transport technologies are a set of methods, tools, and solutions that improve the efficiency of transportation, optimize logistics, and ensure safety and convenience in transportation.

One of the oldest types of transport is water transport. Inventions in water transport have a long history, starting with primitive rafts and canoes used by ancient civilizations like the Egyptians and Mesopotamians for fishing and transporting goods. In Ancient Egypt, around 3000 B.C., the first boats were built from wood and reeds. Later, in Ancient Greece and Rome, more complex designs developed, such as triremes, which had oars and sails that allowed for more efficient use of wind power. Medieval trading ships, like caravels, became popular in the 15th and 16th centuries, increasing trade between continents and opening new routes for exploration and the exchange of goods.

Famous navigator, such as Christopher Columbus, used these ships for their expeditions. Today, the water transport industry uses the most modern technologies and powerful engines, improving the efficiency, safety, and eco-friendliness of transportation.

In China, Rome, and Persia, the building of the first roads and the invention of steam engines started the fast growth of transport technologies. The ideas about steam engines began in the 17th century. The first tests using steam power were done by Denis Papin, who made a simple steam cylinder and piston in 1690.

The most popular steam engine was improved by James Watt in 1769. His engine had an outside condenser, which made it work better by using less fuel. Because of these changes, Watt's engine was used a lot in industries like textiles, metal, and coal. Watt's engine started the big use of steam engines, which helped the Industrial Revolution in Europe. However, when there were problems, the boilers of the engines sometimes exploded like bombs. So, new types of engines were made, like electric motors and internal combustion engines.

The arrival of railways made a real revolution in the development of transport technologies. The development of the first railways in the 19th century fundamentally changed transport, making it faster and more efficient. The first routes in England quickly showed the advantages of railway transport for mass movement of goods and passengers, which helped the growth of heavy industries, especially metallurgy and coal mining.

The first railway in Ukraine, the Lviv-Peremyshl route, was built in 1861 and stretching 97 km. This contributed to economic development, urbanization, and the global spread of railways, making them the foundation of infrastructure for most industrial countries.

During the time when rail and road transport were growing fast, there were also inventions in air transport. Kites in China, which existed hundreds of years before our era, are some of the earliest examples of flight using technology. Some kites could lift a person into the air. Efforts to study the air in the 17th to 19th centuries led to the discovery of gases like hydrogen, which was used to make hot air balloons. Theories in mechanics created by scientists during this time helped develop modern aerodynamics.

The term "aviation" was created by the French aviator Joseph Gabriel in 1863. Tests with gliders made it possible to create heavier-than-air airplanes. At the start of the 20th century, new engines and better understanding of aerodynamics allowed the first controlled flights with powered planes. The first aircraft that could lift off the ground and fly straight was the "Flyer," built by brothers Orville and Wilbur Wright in the United States. The first famous flight of an airplane happened on December 17, 1903.

With the fast growth of ground transport, cities became very crowded. To solve the problem of busy streets and to help move many passengers, people created the subway. Underground trains made travel much faster, helped reduce traffic on the streets, improved the environment, and made the city center quieter.

As a result, the first subway line (3.6 km) was built in London in 1863. In 1868, the subway opened in New York. Later, subways were built in Budapest, Vienna, Paris, Madrid, Barcelona, Oslo, Tokyo, and more.

We should also mention our hometown, Kharkiv. On August 23, 1975, the first section of the modern Kharkiv subway was opened on the Kholodnohirsko-Zavodskyi line. The Kharkiv metro was built not only by professional workers but also by students from local universities, vocational schools, and technical schools.

These "student" groups practiced throughout the construction period. Today, the Kharkiv metro has three lines with a total length of about 38 kilometers and includes 30 stations.

In conclusion, it is worth noting that the development of transport technologies has happened over many years, moving from horse-drawn carts to trains, cars, boats, airplanes, and subways. With each new invention, transport became faster, safer, and easier to use, allowing people and goods to travel longer distances in less time. This led to quick economic growth, better quality of life, and new chances for travel, global trade, and cultural exchange.

Transport technologies have become an important tool that connects communities, makes city life easier, and supports the growth of the modern economy. Today, thanks to new ideas in electric cars, autopilots, and high-speed trains, transport is becoming even more friendly to the environment, safe, and convenient. These technologies aim to reduce the impact on nature and improve our life.

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Shalimova A.M.

TRANSPORT TECHNOLOGIES

Scientific Advisor - lecturer Myrhorod V.O.
Language Advisor - lecturer Myrhorod V.O.

Transportation technologies encompass a wide range of innovations and developments aimed at improving the efficiency, safety, and environmental sustainability of transportation systems. Below are several key areas of focus:

Electric Vehicles (EVs)

Electric vehicles have the potential to significantly improve our quality of life in many ways. EVs do not produce exhaust emissions, which reduces air pollution. This has a positive impact on public health, decreasing the risk of diseases linked to atmospheric contamination. They operate much quieter compared to traditional gasoline and diesel cars, improving life quality, particularly in urban areas where noise pollution is high. Electric motors are more energy-efficient than internal combustion engines, meaning EVs consume less energy for the same distance, lowering fuel costs. EVs have fewer moving parts, which reduces the need for maintenance and repairs, saving both time and money for car owners. They can also be charged using solar panels or other renewable energy sources, which reduces reliance on fossil fuels and lowers the carbon footprint. The use of EVs can decrease countries' dependence on imported oil, contributing to energy independence.

The development of electric vehicle technologies also stimulates innovation and creates new jobs in fields such as electronics, software, battery manufacturing, and green energy. The growing popularity of EVs drives the expansion of charging infrastructure, which is a crucial step toward building more modern and convenient cities. Transitioning to electric vehicles contributes to sustainable development by ensuring a cleaner environment and more efficient resource use. (Hensher.2004)

Autonomous Vehicles

Autonomous vehicles, or self-driving cars, can bring many benefits to society. They have the potential to reduce the number of traffic accidents, as they can respond to situations faster and more accurately than humans. Autonomous vehicles do not get tired, distracted, or influenced by emotions or alcohol. They can optimize traffic flow, avoid congestion, and choose the most efficient routes, reducing travel time and fuel costs. By improving traffic management and reducing congestion, autonomous vehicles can help lower the level of harmful emissions and CO_2.

Autonomous vehicles can provide mobility for individuals who are unable to drive themselves, such as the elderly or people with disabilities. Passengers in autonomous vehicles can use their time on the road for work, rest, or other activities, improving productivity and quality of life.

Reducing traffic accidents can lead to significant economic savings in medical expenses, vehicle repairs, and insurance costs. Autonomous trucks could significantly improve logistics by ensuring faster, more reliable, and cost-effective delivery of goods. Autonomous vehicles can also find and park themselves, optimizing urban space usage. These vehicles could operate as part of public transportation systems, providing on-demand passenger transport and reducing the need for private car ownership.

The development of autonomous vehicles encourages the development of modern infrastructure, including smart roads, vehicle-to-road communication systems, and improved informational infrastructure. Autonomous vehicles represent a revolutionary change in the transportation industry, potentially improving our way of life and enhancing overall road safety and comfort. *(Skinner. 2021*)

Electronic Control Systems

Electronic control systems in transportation will positively impact our lives in many ways. Systems such as automatic braking, lane departure warnings, and tire pressure monitoring can significantly reduce traffic accidents and injuries. Features like adaptive cruise control, automatic parking, and voice command make driving easier and more comfortable, reducing stress for drivers. Intelligent traffic management systems help optimize traffic flow, reduce congestion, and improve travel speeds in cities. This allows for less time spent on the road and reduces air pollution. Electronic systems can monitor the vehicle's condition in real-time and notify the owner when maintenance is required or parts need replacing. This helps avoid unexpected breakdowns and reduces repair costs. Systems such as eco-driving modes and adaptive cruise control help optimize fuel consumption, reducing operating costs and harmful emissions. The use of electronic systems in managing electric and hybrid vehicles increases their efficiency and extends their range on a single charge. Navigation and traffic information systems provide drivers with real-time data on routes, weather conditions, traffic jams, and roadworks. This helps select the most optimal routes and reduces travel time. Driver assistance systems, such as adaptive interfaces and driving aids, make cars more accessible to people with disabilities.

The further development of electronic control systems leads to the creation of autonomous vehicles, which can move without a driver. This opens up new possibilities for improving transportation infrastructure and enhancing transportation efficiency. Overall, the introduction of electronic control systems in transport will improve safety, comfort, efficiency, and environmental sustainability, improving the quality of our lives. (European Commission)

Renewable Fuels

Renewable fuels have the potential to radically change our lives and bring numerous benefits. The use of renewable fuels, such as biodiesel, bioethanol, and hydrogen, reduces greenhouse gas emissions and pollutants. This improves air quality and reduces negative health impacts. Transitioning to renewable fuels decreases dependence on imported oil and fossil fuels, promoting energy security and stability, while reducing risks associated with fluctuating oil prices and political conflicts. Renewable fuels create new jobs in industries related to production, distribution, and research of renewable energy resources. This stimulates economic growth and innovation.

The use of renewable fuels helps conserve fossil resources, such as oil and coal, for future generations. Renewable energy sources, such as solar, wind, and hydropower, are infinite and constantly replenishing. Renewable fuels support sustainable development by contributing to environmentally clean energy and reducing negative impacts on the environment. They help preserve ecosystems and biodiversity. Renewable fuels can lower energy costs for households and businesses, making energy more affordable and stable. This contributes to higher quality of life and economic stability.

The development and implementation of renewable fuels promote scientific and technological progress and innovation. This includes the development of new technologies for the efficient use of solar, wind, and hydropower energy.

Renewable fuels are a key component of an environmentally sustainable future, providing clean, safe, and economically viable energy.

In conclusion, the implementation of modern transportation technologies, such as hybrid cars, autonomous vehicles, electronic control systems, and renewable fuels, has the potential to significantly improve the quality of our lives. These technologies help reduce harmful emissions, increase safety, efficiency, and comfort, lower fuel and maintenance costs, preserve natural resources, and create new jobs. As a result, we can look forward to a cleaner, safer, and more sustainable future for all of us. (Asimann.2004)

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Shevchuk Ye. V.

PROBLEMS AND STUDY OF THE CONDITIONS FOR THE INTRODUCTION OF TRAFFIC LIGHTS AT THE INTERSECTION

Language Advisor – Cand. Ped. Sc., Assoc. Prof. Skrypnyk N. S.

The negative effects of the automotive industry have recently spread to most industrialised countries. This raises a number of serious economic, social and environmental issues. These problems are particularly common in large cities. One of the ways to comprehensively address these problems is to improve the efficiency of the transport system as a whole through the use of the latest technologies, further intellectualisation of automated traffic management systems and methods. Today, the main method of such control is traffic lights at intersections of the city road network.

The need to introduce traffic signal control at a particular intersection is determined by certain criteria based on the intensity of intersecting traffic flows and the occurrence of road traffic accidents (RTAs) at that intersection. The values of intensity of intersecting traffic flows are regulated by the relevant regulatory documents. In addition, traffic lights can be used for large intensive pedestrian flows to places of attraction (cinemas, stadiums, large commercial and industrial facilities, etc.) or when schoolchildren cross the road in the school zone.

The feasibility of using traffic lights is determined by analysing the losses associated with vehicle delays at intersections. These losses depend both on the traffic intensity in the forward and crossing directions and on the adopted traffic light operation modes at the regulated intersection (Powell*,* 2001).

In the leading countries of the world (the USA, Canada, Germany), the main parameter for the introduction of traffic lights is the intensity of traffic flows intersecting at the same level (Olszewski, 1988).

The organisation of traffic at intersections is determined by the intensity of traffic flows at them. If the traffic volume at an intersection is relatively low, the intersection can function as an unregulated one. In this case, the efficiency of such an intersection is determined by a sufficient number of lanes on the approaches to the intersection, as well as by the channelisation of traffic flows. When the traffic intensity increases and reaches certain values, the organisation of traffic at the intersection at the same level becomes possible only with the use of traffic lights.

The introduction of traffic lights eliminates the most dangerous conflict points, which contributes to improved traffic safety. At the same time, the introduction of traffic lights at an intersection causes traffic delays on the main road, sometimes very significant due to the high traffic volume characteristic of this road and the strict programme regulation that prevails in our country in particular.

Thus, the introduction of traffic lights is not always justified and depends on many factors.

Currently, the level of coverage of the street and road network with traffic lights in Ukrainian cities is much lower than in cities in Western Europe, the USA, and Canada. At the same time, the rapid growth of the vehicles observed in our country will inevitably lead to an increase in the level of coverage of Ukrainian cities with traffic control devices.

In such a difficult situation in our country and, in principle, all over the world, in the context of the extremely rapid growth in the number of vehicles on the streets, there are practically no sufficiently clear standards and rules that would unambiguously, in every situation, taking into account local conditions, give an answer to the question if it is necessary or not to introduce traffic lights at a particular intersection.

In this regard, there is an urgent need to develop more precise rules (criteria)or substantially improve the existing ones regarding the need to introduce traffic signalling at intersections.

Having analysed the literature sources, which are used by specialists in our and foreign countries, it turned out that the main parameters for the criteria for the introduction of traffic lights are as follows (National Research Council, 2009).

- intersection capacity (combination of critical intensities on the main and secondary roads);
- accident rate at the intersection (number of accidents per year);
- transport delays;
- technical and economic analysis of the intersection functioning (comparison of losses of the national economy at the intersection with and without traffic lights).

The main objects and conditions for which the introduction of traffic signal control at the road junction is characteristic are

- various intersections at the same level;
- pedestrian crossings;
- railway crossings;
- roads or road sections with reversible traffic;
- roads with one-way traffic;
- places of concentration of road accidents;
- places of repair works;
- various road conditions where the introduction of call signalling is required.

The theoretical boundary conditions for the use of traffic signalling can be determined based on the minimum losses associated with delays at intersections, which depend on the intensity of traffic in the forward and crossing directions and the adopted traffic signal operation modes. On the other hand, there is a methodology for determining the need to introduce traffic signalling at an intersection, which is based on determining the intersection capacity, i.e., determining the critical ratios of intensities on the main and secondary roads.

Assessment of the efficiency (maintenance) of the transport and road complex as a whole and the regulated intersection in particular requires the availability of qualitative measures that characterise the levels of traffic flow management.

Level of Service (LOS) is a qualitative measure that explains the situation in the traffic flow, using such characteristics as speed and time of transportation, freedom of manoeuvre, interruption of traffic flow, as well as convenience and benefit in using this section of the street network (Hobbs, Richardson, 1967).

Currently, for each type of street network element there are several levels of service level, subject to the availability of a special procedure for analysing this element.

Each level represents a range of traffic control states, as well as an assessment of the perception of this range of states by a driver (pedestrian, cyclist). For example, the level of service for a regulated intersection is determined by the value of the control delay, which leads to driver irritation, excessive fuel consumption, and increased correspondence time.

The delay experienced by the driver consists of a number of factors related to the geometric features of the intersection, the control mode, and the intensity of vehicles arriving at the intersection (Taylor, 2002).

The value of transport delay is defined as the difference in time when comparing the movement of a vehicle through a regulated intersection and free movement on the same section without the influence of traffic lights on the traffic flow.

The use of traffic signal control at intersections has an economic effect if the total time loss is less than the loss of unregulated traffic. In this case, it is necessary to take into account traffic safety requirements (Teply, 1995).

It is known that the total time loss in regulated traffic increases with the duration of prohibitive traffic signals and traffic intensity. Hence, it is possible to determine the limit values of these quantities, at which the losses in regulated and unregulated traffic will be the same. Having established such a limit, it is possible to determine the critical traffic volume at which the introduction of traffic signal control is economically justified.

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Tishakov I.O.

MODERN MATERIALS USED IN ROAD AND RUNWAY ENGINEERING

Language Advisor – Asst.Prof. Vorobyova S.V.

The constant evolution of transportation demands necessitates the development and implementation of advanced materials in road and runway engineering. Traditional construction materials often face challenges such as limited durability, susceptibility to environmental factors, and high maintenance costs. Modern materials offer significant improvements in terms of strength, longevity, and sustainability, leading to safer, more efficient, and cost-effective infrastructure.

Classification of Modern Materials

Asphalt Concrete:

- Polymer-modified asphalt. Incorporation of polymers like styrene
- butadiene-styrene (SBS) and styrene-butadiene-rubber (SBR) enhances the flexibility and durability of asphalt concrete, improving its resistance to cracking and rutting, especially in extreme temperature conditions.

- Stone Mastic Asphalt (SMA). This high-density asphalt mixture utilizes a high percentage of stone and fine aggregate, resulting in a robust and durable pavement surface with excellent resistance to deformation and fatigue.
- Warm Mix Asphalt (WMA). WMA technologies utilize additives or processes to reduce the mixing temperature of asphalt, leading to energy savings, reduced emissions, and improved worker safety.

Concrete:

-High-performance concrete (HPC). HPC incorporates special admixtures and aggregates to achieve superior strength, durability, and resistance to abrasion and freeze-thaw cycles.

- Fiber-reinforced concrete (FRC). The addition of fibers, such as steel or synthetic fibers, significantly improves the tensile strength and crack resistance of concrete, enhancing its durability and reducing the risk of catastrophic failures.
- Self-consolidating concrete (SCC). SCC flows easily under its own weight, eliminating the need for vibration, which can be beneficial in congested urban areas and for complex structures.

Polymer Materials:

- Geotextiles. These woven or non-woven fabrics are used to separate, filter, reinforce, and drain soil layers, improving the stability and performance of roadbeds and embankments.
- Geomembranes. These impermeable sheets are used to control water flow, prevent soil erosion, and isolate different layers within the road structure.
- Polymer composites. These materials combine polymers with other materials, such as fibers or aggregates, to create lightweight and high-strength components for road infrastructure.

Other Materials:

-Recycled materials. Utilizing recycled materials such as reclaimed asphalt pavement (RAP) and recycled concrete aggregate (RCA) reduces environmental impact and conserves natural resources.

- Nanomaterials. The incorporation of nanomaterials, such as carbon nanotubes and graphene, can significantly enhance the mechanical properties of construction materials.

Properties of Modern Materials

- High Strength. Modern materials are designed to withstand heavy traffic loads and extreme environmental conditions.
- Durability. These materials exhibit excellent resistance to wear, tear, fatigue, and environmental degradation, leading to extended service life and reduced maintenance costs.
- Flexibility. Many modern materials exhibit improved flexibility, allowing them to better accommodate traffic loads and temperature fluctuations.
- Sustainability. The use of recycled materials and the development of environmentally friendly production processes contribute to a more sustainable approach to road and runway construction.
- Cost-effectiveness. While initial costs may vary, the long-term benefits of improved durability and reduced maintenance often result in significant cost savings over the life cycle of the infrastructure.

Modern Technologies and Applications

- 3D Printing. 3D printing technology is being explored for the construction of complex road and runway components, offering greater design flexibility and reduced construction time.

- Self-healing materials. These innovative materials can repair minor cracks and defects autonomously, extending the service life of infrastructure and reducing maintenance requirements.
- Smart pavements. The integration of sensors and other technologies into pavement structures enables real-time monitoring of traffic conditions, pavement performance, and environmental factors, allowing for proactive maintenance and improved traffic management.
- Recycled materials. The increasing use of recycled materials, such as RAP and RCA, not only conserves natural resources but also reduces the environmental impact of construction and waste disposal.

Table 1 - Comparison of Different Material Types

Material Type	Strength	Durability	Cost	Environmental Impact
Asphalt Concrete	High	Moderate	Moderate	Moderate
Concrete	Very High	High	High	Moderate
Polymer Materials	High	High	Moderate to High	Moderate to Low
Recycled Materials	Moderate to High	Moderate	Low	Low

Conclusions

Modern materials play a crucial role in advancing road and runway engineering by offering improved performance, durability, and sustainability. Continued research and development in this area will lead to the creation of even more innovative and efficient solutions for future transportation infrastructure. The incorporation of these advanced materials will not only enhance safety and efficiency but also contribute to a more sustainable and resilient transportation system.

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Vitruk I. S.

THE DIFFERENCE BETWEEN THE TWO TYPES OF ENGINES INSTALLED IN TRUCKS

Scientific Advisor – DSc (Engineering), Prof. Podryhalo M. A.
Language Advisor – CandSc (Education), Assoc. Prof. Borzenko O. P.

Let's consider at the differences between the two types of engines, focusing not only on the engines themselves, but also on the components that differ between them.

Diesels are known to last hundreds of thousands of miles. Some people even joke that they aren't even completely broken down until you reach 100,000 miles. Diesel trucks produced before 2005 had very low emission requirements and therefore did not have the same emission systems as new diesel engines. Generally speaking, diesel engines are built with stronger engine blocks and internal components to withstand significantly higher compression ratios than gas engines. Therefore, they generally withstand more intensive work for longer periods of time than gas engines.

If the engine is only occasionally subjected to heavy load, gas engines can last just as long. With new diesels, engines can be as durable as older diesels. However, due to stricter emissions restrictions, there are a number of expensive components that will affect the truck's durability of the. For those who plan to keep their trucks for a long time, manual transmissions are generally cheaper to operate.

As a rule, technical maintenance of a diesel engine will cost more than a gas engine. Diesels hold more oil, so change is more expensive. Besides the fuel and exhaust systems, there are many filters and components that need to be changed that you won't find on gas engines. Newer diesel engines also require diesel exhaust fluid, which must be added to meet emissions requirements.

Diesels operate at lower revs, which reduces wear on many engine components. Diesels can offset higher operating costs when operating under severe conditions for long periods of time. Under these conditions, gas engines are likely to have more expensive internal failures than diesel engines.

Fifteen years ago, it was common to see more than 25 miles per gallon from a heavy-duty diesel engine. Now, most drivers see less 20 miles per gallon. On the other hand, light-duty and mid-size diesel trucks today can have EPA ratings of up to 30 miles per gallon. If the truck is used to carry light loads over long distances, then a half-ton or mid-size diesel may be the best choice – again, diesel engines work best under heavy loads. A heavily loaded diesel generally returns more miles per gallon than an evenly loaded gas engine.

That is, if a heavy-duty pickup truck is needed day in and day out, a diesel engine will likely save money on fuel. If the truck will only be carrying a light load or traveling empty, a mid-size pickup truck with a diesel engine will cost less to fuel than a comparable truck with a gas engine.

Again, it depends on how the pickup truck is used. If it carries heavy loads daily and will be used for over 200,000 miles before change, a diesel will likely be cheaper in the long run. If the truck's main purpose is to pull a camping trailer that's well below the truck's maximum towing capacity, or to look cool while grocery shopping, then a gas engine will likely be less expensive. The previous cost of a heavy-duty diesel could be more than $10,000 more than an equivalent gas engine. These costs are directed towards the engine itself, a more powerful transmission, and additional emissions components.

For mid-size and light-duty pickups, a diesel engine significantly improves fuel economy, and the diesel option only costs about $3,000–$5,000 more than gas.

If the truck gets a lot of miles each year, the better fuel mileage can offset the extra cost of a diesel engine over a few years. This generally involves paying a little more money for diesel than for gasoline.

For towing, a diesel engine is almost always the better option. Diesels have a lot of torque at low revs, which is what you need when towing. They get better fuel mileage under heavy loads and last longer. Another nice aspect of most diesel engines is the integrated exhaust brake. This greatly helps in controlling the truck and trailer when descending steep hills or when driving in traffic. The exhaust brake slows the truck by using back pressure from the turbocharger to slow the engine. The presence of this additional braking method reduces wear on the brake system and also reduces the chance of brake overheating.

The trucks with gas engines often have higher payload capacities than equivalent trucks with diesel engines because diesel engines and related systems weigh significantly more than their gas counterparts. The diesel's power and exhaust brake will still be useful when carrying heavy payloads, but if the truck is operating at its limits, the lighter weight of the gas engine will allow for increased payload.

The obvious choice for power in the heavy-duty engine market is diesel. Modern gas engines simply can't match diesels when it comes to torque. Diesel is suited to heavy-duty everyday work and can work where a gas engine simply cannot.

For light and medium pickups, the torque advantage gained from a diesel engine does not exceed the power of equivalent gas engines. The additional power of gas engines with faster, higher revs makes them quicker for spirited driving. Diesel engines in these classes are designed for maximum efficiency, but are still capable of performing most tasks. Heavy-duty engines are designed for maximum power while remaining reliable. The extra weight of a diesel engine in the front of a truck can damage off-road driving if the vehicle gets stuck in mud or sand. Gas engines rev faster and have a higher redline. This gives them a wider operating range of revs in each gear, which is good for desert driving and cleaning mud out of the tires.

Diesel engines, especially when equipped with manual controls, offer better control at low-speed for rock crawling. The slow torque at low revs is great for getting the vehicle moving up steep hills without spinning the tires. Additionally, with the extra torque from the diesel engine, the truck will be able to turn over larger tires more easily.

For on-road driving, rather than for severe off-roading, diesel engines are preferred due to their improved fuel economy and durability. Diesel engines are widely used because they are often more reliable and can operate on lower quality fuel. Organizations such as the Red Cross, Peace Corps, and the United Nations use Land Rovers and Land Cruisers jeeps with diesel engine due to their reliability in harsh, dusty, and dirty conditions.

There is no clear winner between gas and diesel engines. Each performs better in certain areas; it all comes down to how the truck will be used and what the owner prefers.

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Voronkina V. R.

LOGISTICS STRATEGIES: CONCEPTS AND TYPES FOR MODERN ENTERPRISES

Language Advisor – Asst. Prof. Chevychelova O. O.

Modern market conditions emphasize the important role of enterprises in the functioning of the economy, and the efficiency of their work, rapid development, and ability to remain competitive largely depend on the quality management of logistics activities. Logistics is an integral part of the activities of every enterprise, as it covers the entire process from production to the end consumer, including transportation, storage, and processing of goods. Given the complexity of this process, there are different interpretations of the term "logistics" in the scientific literature because it includes many aspects, and the emphasis on one or another can significantly change the meaning of the definition. Logistics is generally defined as the process of planning, organizing, and implementing optimal transportation and storage of goods to deliver them to consumers on time at minimal cost. The main goal of logistics is to meet customer needs in a way that is cost-effective and timely. An important aspect is that the logistics activities of an enterprise involve not only physical flows of goods but also information flows that provide a connection between all stages of the supply chain, allowing for a timely response to changes in demand and market conditions.

In the context of organizing logistics at an enterprise, several main areas can be distinguished. Logistics strategy is defined as a set of certain types of logistics activities and operations that create a long-term logistics strategy for the company. According to the traditional classification, there are two main strategies: a thin (or "lean") logistics strategy focused on minimizing costs and a dynamic logistics strategy focused on the level of customer service. The thin logistics strategy ensures that all operations take place with minimal resources, such as labor, financial, space, and time costs. The main task is to ensure high efficiency at minimal costs. The dynamic logistics strategy involves the company's ability to respond quickly to changes in demand, providing a high level of service and meeting consumer requirements through operational actions.

In addition to these two traditional strategies, scientists also distinguish other types of logistics strategies. Thus, O. Rudkivskyi in his article suggests highlighting a strategy focused on productivity, which optimizes logistics costs while providing a high level of service for consumers. It allows the company to reduce the cost of logistics operations while not reducing the quality of customer service.

N. Ilchenko in her monograph indicates another important strategy, characterised as a strategy of strategic alliances between suppliers and customers. This approach is based on the integration of the supply chain through close cooperation between partners. Such a strategy increases the efficiency of the entire supply chain and achieves savings through joint efforts.

It is also worth noting that some researchers distinguish a wider range of strategies. I. Palchyk, after systematising logistics strategies, identifies five main types of logistics strategies that are most relevant for enterprises in modern conditions: strategy for reducing logistics costs through process optimisation and significant investments in logistics infrastructure development; strategy for maximising and improving the level of logistics service, ensuring a high level of customer service and increasing customer satisfaction; strategy for maximising income and profit by optimising logistics processes to increase the company's financial performance; strategy for increasing the competitive advantages of the enterprise, ensuring market stability through effective supply chain management and meeting specific consumer needs; logistics outsourcing strategy, involving transferring part of the logistics functions to third-party service providers to reduce costs and focus on the company's core business processes.

Logistics strategies can also be further classified by risk level into the following types: a conservative logistics strategy – minimising the risks of logistics operations through the use of proven methods and technologies, as well as diversifying logistics supply chains, and an aggressive logistics strategy – maximising the benefits of logistics operations through the use of new technologies, outsourcing logistics functions, or entering new markets.

Given the variety of strategies in logistics management, each approach has its own characteristics and requires careful implementation. Since logistics covers a wide range of processes – from transportation and storage of goods to information flow management – it is crucial for enterprises to adapt their strategies flexibly to constantly changing market conditions. The right choice of strategy depends not only on reducing costs or increasing the level of service but also on the ability of the enterprise to compete successfully while maintaining stability and efficiency.

It is also important to integrate modern technologies into logistics processes. Information systems, automation, big data analysis, and innovation in logistics management processes can significantly increase the efficiency of the entire system. The logistics development strategy should take into account not only traditional methods of supply chain management but also the opportunities provided by digitalisation to ensure more accurate and rapid responses to changes in demand and market conditions.

In addition to the primary strategies outlined, modern logistics management is increasingly influenced by the globalisation of markets, evolving customer expectations, and the rise of e-commerce. As businesses operate in more complex and competitive environments, it is crucial to integrate these external factors into logistics strategies. One such strategy is the global logistics strategy, emphasising the effective management of supply chains spanning international borders. This strategy involves overcoming logistical challenges related to customs regulations, international transportation, and supply chain complexity, while taking advantage of cost differences between regions.

Another important strategy is the sustainability-oriented logistics strategy. With growing concerns about environmental impact and regulatory pressures, businesses are adopting more sustainable practices, such as reducing carbon emissions, optimising transportation routes to minimise fuel consumption, and using eco-friendly packaging. This strategy not only meets regulatory requirements but also enhances the company's reputation among environmentally conscious consumers. Sustainable logistics can also lead to long-term cost savings as it reduces waste and improves resource efficiency.

Another emerging concept in logistics is the resilience strategy, which aims to improve the supply chain's ability to withstand and recover quickly from disruptions, whether caused by natural disasters, geopolitical instability, or unexpected demand changes. Companies adopting resilience-oriented logistics strategies focus on creating flexible, adaptive systems that can quickly switch suppliers, routes, or methods of transportation in response to unforeseen challenges. This approach includes advanced forecasting, risk management, and business continuity planning.

Additionally, digital transformation strategies are playing an increasingly central role in logistics management. As technology continues to evolve, companies are integrating Internet of Things (IoT) devices, artificial intelligence (AI), machine learning, and blockchain technologies into logistics operations. These innovations allow for real-time tracking, predictive analytics, and greater transparency across the entire supply chain. Logistics professionals can leverage big data analytics to optimise delivery schedules, predict demand patterns, and even prevent disruptions before they occur. The implementation of blockchain in logistics also improves the security and traceability of goods, reducing fraud and ensuring transparent and verifiable transactions.

The integration of technology also supports the development of omnichannel logistics strategies. As consumer preferences shift toward seamless shopping experiences combining online and offline interactions, companies focus on aligning logistics operations with multiple sales channels. An omnichannel strategy involves ensuring that products are available for order and can be efficiently delivered, regardless of whether customers choose to buy online or in-store. This requires sophisticated inventory management systems, efficient distribution networks, and the ability to manage complex reverse logistics for returns and exchanges.

Finally, the customer-centric logistics strategy emphasises understanding and anticipating customer needs to enhance their overall experience. Companies focusing on this strategy aim to create a logistics process that aligns with customer expectations, particularly regarding delivery speed, product availability, and flexibility. This can involve solutions such as same-day or next-day delivery, personalised delivery options, or using predictive analytics to better forecast consumer demand.

In conclusion, while traditional logistics strategies of cost minimisation and service maximisation remain essential, the modern business environment requires a more diversified and flexible approach. By considering emerging trends such as global supply chains, sustainability, digital transformation, resilience, and customer-centricity, enterprises can adapt their logistics strategies to stay competitive and responsive in an increasingly complex and fast-paced market.

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5.

TOURISM, HOTEL AND RESTAURANT BUSINESS

Hulak Y.Y.

CHALLENGES AND ADAPTATION OF THE TOURISM AND HOSPITALITY SECTOR IN TIMES OF WAR

Scientific Advisor –Doc. of Econom. Sciences, Prof. Obolentseva L.V.
Language Advisor –Cand. of Philol. Sciences, Asst. Prof. Plotnikova N. V.

The tourism and hospitality industry is constantly facing a number of different challenges. Some of them can be foreseen, prevented, and addressed, but the war "entered" the lives of Ukrainians suddenly and without asking. It has had too much impact on the tourism and hospitality industry, creating obstacles to further development.

Therefore, the purpose of this study is to analyze the tourism and hospitality sector in the context of war and the issue of adaptation of the tourism industry to the current conditions.

In the first days of Russia's invasion, the most likely options for businesses were two: to cease operations, i.e., to close or to continue providing relevant services. Accordingly, while some hotels closed, others engaged in charitable activities to help internally displaced persons and other people who faced serious accommodation problems due to the war. Tour operators helped with accommodation, and restaurants provided food. The tourism industry came together to help in this difficult time.

At the same time, almost 2,000 accommodation facilities in eastern, northern, and southern Ukraine were forced to stop their operations due to the occupation and proximity to the front line (Mind.ua, 2024).

Almost a year later, most of the hospitality and tourism industry was able to adapt to the new reality and began to open businesses in the more conventionally calm western regions.

According to a study by the State Agency for Development of Ukraine (DART, 2024) for the first half of 2024, five regions and the city of Kyiv have the highest amount of taxes paid by the tourism industry. These regions include Dnipropetrovska - UAH 59.5 million, Odesa - UAH 60.6 million, Ivano-Frankivsk - UAH 119.5 million, Kyiv - UAH 123.8 million, Lviv - UAH 194.8 million, and Kyiv city - UAH 389.9 million. The smallest amount of taxes is observed in the following regions: Luhansk - UAH 0.03 million, Kherson - UAH 1.1 million, Donetsk - UAH 5.8 million, Sumy - UAH 6 million, Chernihiv - UAH 6.8 million, and Zhytomyr - UAH 8.4 million (Table 1) (ДАРТ, 2024).

Table 1

Dynamics of taxes paid by tourism enterprises in the 1st half of 2024

Regions	**2022**	**2023**	**2024**
Vinnytsia	11,5	11,7	17,2
Volyn	6,0	6,8	11
Dnipropetrovska	35,0	43,1	59,5
Donetsk	13	3,6	5,8
Zhytomyr	4,6	6	8,4
Transcarpathian	33,2	35,9	52,2
Zaporizhzhya	17,6	6,2	15,5
Ivano-Frankivsk	106,2	58,3	119,5
Kyiv	63,2	111,2	123,8
Kirovograd	5,7	6,4	10,3
Luhansk	1,8	0,2	0,03

Lviv	129,9	147,9	194,8
Mykolaiv	9,4	7,5	11,1
Odesa	42,8	43,4	60,6
Poltava	17	18,2	28,9
Rivne	6,7	7,8	13,2
Sumy	4,7	4,5	6
Ternopil	8,7	8	12,8
Kharkiv	24,6	16,2	22,8
Kherson	9,3	0,7	1,1
Khmelnytsky	11	11,3	16,3
Cherkasy	8,8	8,2	13,6
Chernivtsi	9,1	13,1	17,6
Chernihiv	7,6	4,2	6,8
м. Kyiv	222,8	229,8	389,9

In order to operate successfully, hotels need to adhere to the following points: balanced planning, location, supply chain analysis and correction, improved resource utilization, flexible pricing, electricity use, cost-consciousness, and a versatile staff (Ribas Hotels Group, 2023).

You should also keep in mind that the safety of visitors is of paramount importance, so it's best to equip a bomb shelter with amenities to ensure a comfortable stay. A generator will not be superfluous, especially in winter when there are long power outages. And the last important factor is to provide services to make the guest feel welcome. After all, it is during these difficult times that people need a sense of calm and joy.

So, despite the problems identified due to the war, the tourism and hospitality sector has managed to adapt and improve its position. This gives businesses an incentive to look for new methods of providing services more successfully.

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Klosova A. D.

RENNOVATION AS AN INNOVATIVE APPROACH TO THE DEVELOPMENT OF HISTORICAL AND CULTURAL TOURISM

Language Advisor – Asst. Prof.Candidate of Philological Sciences PlotnikovaN. V.
Scientific Advisor - Asst. Prof.Candidate of Architecture MartynenkoA. S.
Asst. Prof.Candidate of Architecture Kudryashova I. V.

Today, the topic of saving cultural heritage is extremely relevant. One of the way to popularize heritage is the development of historical and cultural tourism. Historical and cultural tourism is one of the most popular sector of the tourism industry. The main goal of this type of tourism is to attend sites that reflect the history and culture of a certain region. Historical and cultural tourism promotes popularization and preservation of heritage while fostering national identity. Thus, there is a growing need for innovative approaches to preserving objects that represent history and culture. One such approach is renovation.

The topic of renovation in the context of historical and cultural tourism is highly relevant worldwide, as giving new life into abandoned architectural sites has become a key trend in modern architecture. A renovated site becomes a new magnet that attracts tourists by reflecting the culture and local history while offering a variety of new functions.

Renovation (restoration) is a comprehensive approach to preserving historical and cultural heritage objects and adapting them to the modern world by partially or completely changing their function. It is a symbiosis of development and innovation with heritage preservation. The main key to restore the exterior of morally and physically outdated buildings and structures while modernizing the internal layout to meet contemporary standards and using modern materials (ДБН, 2019). Renovation opens new opportunities for tourism at the same time saving authenticity, thus increasing the appeal of the site. Successful examples of renovation include restoration of manors, castles, industrial structures, and more. These projects not only preserve historical landmarks but also attract targeted tourist groups, create new jobs, and stimulate the development of related industries. Renovation projects directly contribute to economic growth in a region by creating jobs.

One of the main aspects of renovation is preserving the authenticity of historical structures. Innovative technologies used during the process of renovation give possibility to minimize interference with the original structure, maintaining its historical value. On the one hand it ensures the protection of cultural heritage, on the other hand, it creates conditions for more comfortable and modern use of these objects. For example, modern climate control, lighting, or security systems can be installed during renovation, enhancing visitor comfort without disrupting the architectural harmony of the site.

Renovation is also a sustainable solution, as it involves the reuse of existing buildings. Renovation projects encourage investment in infrastructure, such as the development of hotels and restaurants. These sites can serve as hubs for themed tourist routes, such as festivals, concerts, and other cultural events, acting as catalysts for the further promotion of the region.

Restoration of historical sites provides new generations with the opportunity to engage more closely with the history of their own or other regions, appreciate cultural values and traditions from a fresh perspective. Often, to promote tourism, outdated sites are transformed into cultural centers, museums, or shopping and entertainment complexes (Буравченко, Горбунова 2020].

Several factors influence the functional direction of a building undergoing renovation:

- Location of the site;
- Historical and cultural value;
- Original purpose.

The original purpose of a site can inspire the selection of its new function, which may become the thematic focus of the renovated site.

International experience demonstrates that successful renovation projects often become tourist attractions in their own right, serving as key destinations for travelers. Rotermann Quarter, Tallinn, Estonia is the project of transformation an industrial urban area into a modern cultural and tourist center, making the historical district attractive to tourists, locals, and investors.

Zollverein Coal Mine, Essen, Germany was founded in 1847 and once one of the largest coal mines globally, Zollverein was designated a UNESCO World Heritage Site in 2001, highlighting its historical and cultural value. The renovation preserved its architecture while repurposing the site into cultural centers, museums, and exhibition spaces. Today, Zollverein hosts film festivals, concerts, modern art festivals, and other cultural events, drawing visitors worldwide and contributing to the region's economic and cultural growth.

Landschaftspark Duisburg-Nord, Duisburg, Germany originally was a steel plant closed in 1985, the site was converted into a unique park offering attractions like rock climbing on industrial structures, scuba diving in former gas tanks, and night light installations. It has become a popular location for active recreation, cultural events, and eco-tourism while preserving the industrial heritage of the area (3).

These examples illustrate that well-designed renovation projects can transform sites into tourist attractions while supporting the development of related industries.

In conclusion, renovation is a vital tool for preserving historical and cultural heritage and a key driver of tourism development. By combining traditions with modern needs, renovation retains the authenticity of historical sites while giving them new life. Through renovation, a site evolves from being merely a relic of the past to becoming an active participant in contemporary and future life. This underscores renovation as an innovative and essential approach to developing historical and cultural tourism.

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Kuchashvili D. S.

GLOBAL EXPERIENCE IN CREATING SITE-SPECIFIC MUSEUMS FOR TOURISM DEVELOPMENT

Scientific Advisor –Candidate of Architecture,Asst. Prof. Kudryashova I. V.
Scientific Advisor –Candidate of Architecture,Asst. Prof. Martynenko A. S.
Language Advisor –Candidate of Philological Sciences,
Asst. Prof. Plotnikova N. V.

Expressive and emotionally engaging, site-specific museums have become a significant element of contemporary architecture and tourism. They not only preserve cultural and natural heritage but also create new tourist routes, stimulating regional development. The growing relevance of such museums is linked to the necessity of integrating architecture into natural and historical environments, meeting the demands of an ecologically conscious society and the quest for unique cultural experiences. These projects combine sensitivity to context, the use of local materials, and deep respect for history and landscape, creating a powerful tool to draw attention to local landmarks. In the context of globalization, site-specific museums address the challenge of preserving local identity while simultaneously serving as tourist attractions capable of transforming the socio-economic landscape of entire regions.

A site-specific museum is a cultural institution that interprets the history, culture, nature, or unique features of a specific area or region through architecture. Its primary characteristic is a strong attachment to a particular location, often referred to as the "genius loci" or the spirit of the place, and its role in shaping the identity of that area. Such a museum does not merely display exhibits; it enables visitors to experience direct interaction with the site, making architecture an integral part of the exhibition. Site-specific museums are often established in areas of significant cultural, historical, or natural importance, such as ancient ruins, unique natural landscapes, or historic buildings.

The concept of site-specific museums may be rooted in various architectural approaches, such as symbolism or architectural phenomenology. Due to the emotional aspects of architecture, these museums act as tourist magnets, attracting travellers seeking unique cultural and natural experiences. They also contribute to the development of sustainable and culturally responsible tourism, respecting the local context.

In contemporary architecture, site-specific museums employ diverse techniques and methods to create unique spaces that blend seamlessly with their surroundings. One key approach is the use of local materials and resources. This allows the museum to harmoniously integrate into its natural or cultural context, enhancing its authenticity. For example, architects may use stone, wood, or other materials characteristic of the region to emphasize the connection between architecture and the landscape. Another essential aspect is architectural integration with the landscape. Modern museums often avoid imposing forms and strive to harmonize with their surroundings. This approach helps create a sense of natural space, where architecture does not compete with nature but accentuates its significance.

Innovative technologies and sustainable solutions also play a crucial role in contemporary site-specific museums. Increasingly, technologies are utilized for building energy efficiency, interactive exhibits, and resource conservation. Implementing energy-saving systems, natural ventilation, and renewable energy sources enables museums to serve not only as cultural institutions but also as examples of sustainable development. These solutions help minimize environmental impact, which is critical for tourism in ecologically sensitive areas.

Some site-specific museums in contemporary architecture have become exemplary in blending architectural solutions with natural or cultural contexts. First, there are museum projects that reflect natural processes or phenomena, creating a unique interaction between architecture and nature. *Roden Crater* by James Turrell is an example of integrating architecture with the natural landscape, where the volcanic crater itself becomes part of the museum space. Turrell uses this natural formation to create unique experiences of light and space, transforming it into a "tool for observing the sky." Here, architecture acts as a mediator between humanity and the space, shaping a space for intuitive perception of natural phenomena. The spatial morphology, essentially an art object and a symbolic cosmic code, is enhanced by unique lighting solutions.

Another example is Vulcania by Hans Hollein in France, which also focuses on natural phenomena, particularly volcanic activity. The museum's architecture abstractly represents volcanic processes, using concrete and stone to create a space reminiscent of lava flows and volcanic rocks. This museum not only presents scientific facts but also allows visitors to physically experience the "presence" of volcanic activity through interaction with architecture. In Vulcania, architecture becomes a tool for interpreting natural processes, creating a strong tourist attraction.

Another important group of site-specific museums integrates contemporary architecture with historic environments. A notable example is the Kolumba Art Museum in Cologne, designed by Peter Zumthor. The museum building rises on the ruins of an ancient Gothic church partially destroyed during the WW2. Zumthor incorporated preserved elements into the modern structure, creating a complex, multilayered space where the past and present intertwine. This approach allows visitors to simultaneously immerse themselves in history and experience contemporary art. Kolumba exemplifies a sensitive approach to preserving cultural heritage, where architecture does not dominate history but coexists harmoniously with it.

The third group includes museums that integrate ecological and sustainable architectural approaches. The Water Conservancy Center in Zhejiang Province, China, designed by DnA, is an excellent example of how museums can play a crucial role in promoting ecology and sustainability. The museum's architecture blends seamlessly with the reservoir landscape, emphasizing the importance of water conservation. Using local materials and environmentally responsible solutions makes this museum a benchmark for sustainable design. Additionally, it serves not only as an exhibition space but also as a venue for environmental education, where visitors can learn about the significance of nature conservation. The Water Conservancy Center supports eco-tourism while highlighting environmental values.

The analyzed prototypes of site-specific museums demonstrate the key principles underpinning their design and integration into natural or historical contexts. First is a profound understanding of the site and its natural or cultural characteristics. Architects of site-specific museums begin by studying the specifics of the landscape, regional history, and cultural significance to ensure their solutions are not alien but organically complement the environment. In these museums, the concept of "genius loci" plays a pivotal role, shaping both the project's overall idea and its details.

The second principle is the selection of materials that align with the local context. Site-specific museums often utilize regionally available materials such as stone, wood, clay, or concrete, which not only visually integrate the building with the landscape but also preserve authenticity and sustainability. For example, in the Water Conservancy Center, the architecture literally grows from the landscape through the use of local materials, highlighting the inseparable connection between the building and the aquatic ecosystem.

The third principle is a phenomenological approach to space, where architecture is not just functional but becomes part of the emotional and sensory experience of visitors. This approach is evident in the Roden Crater and Kolumba Art Museum, where architecture interacts with human perception, creating spaces for reflection, contemplation, and immersion in history or nature. Such interaction fosters a strong emotional connection to the site, attracting visitors from around the world.

The final principle is sustainability and ecological responsibility. Site-specific museums often serve as models of sustainable construction. They consider the environmental impact of construction, apply energy-efficient solutions, and use natural resources in ways that minimize harm to the surrounding environment. Such measures are crucial, as most site-specific museums are located in natural or ecologically sensitive areas, making environmental preservation an integral part of their concept.

In conclusion, site-specific museums effectively preserve cultural and natural heritage while serving as powerful tools for tourism and regional economic development. Integrating architectural projects into natural and historical contexts allows for the creation of unique spaces that harmonize with the landscape, preserving local identity. Through the use of local materials, environmentally conscious approaches, and sensitivity to context, such projects address contemporary global challenges, particularly the need for sustainable and responsible tourism. Moreover, site-specific museums not only support the preservation of local landmarks but also contribute to the creation of new tourist routes, stimulating the socio-economic growth of regions—a particularly valuable asset in the era of globalization.

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Parasiuk V. R.

PRINCIPLES OF NATURAL ZONE DEVELOPMENT WITHIN THE TOURISM NETWORK OF SLOBODA REGION

Scientific Advisor – Candidate of Architecture,
Asst. Prof. Martynenko,
Scientific Advisor – Candidate of Architecture,
Asst. Prof. Kudryashova I. V.
Language Advisor – Candidate of Philological Sciences,
Asst. Prof. Plotnikova N. V.

The natural zones of the Sloboda region represent a significant ecological and cultural resource with substantial potential for tourism development. However, a major challenge is the degradation of these areas due to a lack of proper management, pollution, and unsystematic use. Addressing this issue requires new approaches to preserving and developing natural zones, especially in the context of ecotourism.

The relevance of integrating natural zones into the tourism network of the Sloboda region stems from the need for balanced utilization of the region's unique natural landscapes for tourism, while maintaining ecological equilibrium. Amidst a global ecological crisis, the demand for responsible approaches to resource use is growing. Sloboda, with its natural and cultural wealth, has the potential to become a leading ecotourism hub in Ukraine, combining environmental responsibility with economic benefits. Integrating ecological principles into the development of the region's tourism sector is critical to preserving natural ecosystems.

Ecological sustainability is essential for the development of natural zones. Sustainable development involves using eco-friendly materials, energy-efficient technologies, and incorporating natural elements into the spatial planning of buildings and infrastructure. For Sloboda, this means tourism facilities should focus not only on attracting visitors but also on maintaining ecological balance. Designing tourist infrastructure in Sloboda's natural zones should emphasize harmonious integration of architectural elements into the landscape. Tourist structures such as observation decks, eco-trails, information centers, recreational areas, hotels, and relaxation parks should respect the natural environment and preserve its visual integrity. Using natural materials can reduce the visual impact on the landscape and promote environmentally friendly construction. Additionally, architectural solutions should be flexible, adapting to environmental changes, including climatic and seasonal fluctuations.

Ecotourism is a cornerstone of sustainable development for Sloboda's natural zones. This form of tourism promotes a responsible attitude toward the natural environment, supports conservation, and provides economic benefits to local communities. Sloboda boasts significant potential for ecotourism, offering diverse landscapes, rich flora and fauna, and a wide array of natural heritage sites. The region includes 135 areas and objects of natural heritage, such as Krasnokutsky Arboretum, Nataliivsky, Staromerchansky, and Sharivsky Parks. These areas are not only valuable for their biodiversity but also hold cultural and historical significance. They can serve as centers for ecotourism development, combining opportunities for ecological education, recreation, and cultural enrichment for visitors, while fostering regional economic growth through investment and job creation for local residents.

Key aspects of ecotourism development:

- Economic aspect: enhancing resource capitalization, particularly underutilized ones, to alleviate pressure on heavily exploited resources.
- Ecological aspect: reducing environmental impacts by minimizing waste, promoting recycling, and adopting more rational resource use practices to maintain ecological balance. Preserving biodiversity and ecosystems is vital for ensuring environmental stability.
- Social aspect: supporting traditional occupations and increasing job opportunities. Tourism engages local communities in various activities, such as agritourism, handicrafts, and cultural events, thereby boosting the local economy and preserving cultural traditions.

- Cultural aspect: integrating cultural elements into the development of tourist zones creates unique offerings while preserving cultural identity.

Key challenges include preserving the natural environment, adapting to climatic conditions, and mitigating the adverse impacts of mass tourism. Mass tourism can lead to resource degradation, environmental pollution, and ecosystem disruption. Effective strategies must be implemented to manage tourist flows, such as visitor limits, alternative routes, and raising tourists' ecological awareness.

The development of Sloboda's natural zones within the tourism network, guided by ecotourism principles, is a vital tool for the region's sustainable development. Integrating ecological, social, economic, and cultural dimensions will preserve natural resources, drive economic growth, and create new opportunities for the tourism industry. Ecotourism enhances ecological awareness, protects biodiversity, and supports local communities, making natural zones a critical component of Sloboda's sustainable future.

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PSYCHOLOGY AND HEALTH

Sierykh Y. S.

THE IMPACT OF STRESS ON HUMAN LIFE AND HEALTH

Language Advisor – Senior Lecturer Tykhonova M.Ye.

One of the most harmful threats to psychological and physical health is stress. Based on the experiences of many people during the war, stress levels can be divided into three states: moderate, very strong, and constant.

Moderate stress arises from specific situations and allows a person to return to normal both physically and psychologically relatively quickly. It can result from everyday activities and ordinary challenges such as work, study, or social interactions.

Very strong stress is the most intense level. It represents a state of heightened arousal and mobilization of all resources, where a person is extremely tense, struggles to sleep or eat, and operates outside emotional, hormonal, and psychological balance. This mechanism often activates as an adaptation to extraordinary events, such as the full-scale invasion of Ukraine.

Constant stress develops as an adaptation to prolonged exposure to severe stress. If the triggering stimulus persists, the individual may seem to adjust to this new lifestyle, giving the impression of overcoming stress. However, the body functions differently: cortisol levels remain consistently high, unregulated by other hormones, and the nervous system stays in a state of heightened arousal. This results in persistent physical and emotional tension.

For instance, during the war, individuals who have experienced traumatic events often operate like a "radar," using all their senses to detect potential dangers. After severe stress, if the stimulus does not disappear and hormonal balance cannot be restored, adaptation occurs over time, but the process is highly individual for each person.

Every individual unconsciously chooses a behaviour model to cope with tension and arousal. These models can be categorized as follows:

Delayed life syndrome – when a person is unable to move forward and simply waits for the stress to end.

Maximizing life experiences – when an individual strives to get the most out of life. This sense of fulfilment helps to manage stress and maintain functionality.

A balanced approach – when a person gradually resumes normal life and plans for the future. They neither ignore the situation nor fully immerse themselves in it but continue living with considerable psychological and emotional strain.

The choice of behaviour is subconscious and influenced by various factors that either reduce stress or prevent it from escalating. Over time, individuals can consciously or unconsciously shift their coping strategy.

Regardless of the coping model, people in constant stress share one short-term mechanism for stress relief: adrenaline. For example, in the realities of war, life under stress becomes habitual, like breathing. Until an explosion or other traumatic event occurs, it feels as though one is "holding their breath." When an irritant appears, adrenaline is released, providing a brief sense of "normalcy," much like a breath of air for someone who has been suffocating.

This is entirely natural, and individuals should not blame themselves for it. Instead, they can acknowledge: "Yes, I want this, maybe I'm even waiting for it," and "Yes, I understand the consequences and do not welcome them." This response stems from physiological processes beyond conscious control, which provide temporary relief and a feeling of being almost free from stress.

In summary, severe stress significantly impacts a person's life and functioning. Initially, the body mobilizes all its resources to cope, and over time, it adapts, resulting in physiological and psychological changes. Chronic stress not only affects psychological well-being but also poses risks to physical health. Persistent high cortisol levels can lead to conditions such as cardiovascular diseases, weakened immunity, gastrointestinal issues, and even memory impairment. Recognizing and addressing chronic stress is vital to preventing these long-term health consequences. Understanding these processes can help individuals avoid blaming themselves or misinterpreting their desires. It is important to recognize and accept the profound influence of external factors on human life.

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NATURAL SCIENCES

Onishchenko A. V.

CIRCULAR ECONOMY AND LOGISTICS: CREATING CLOSED CYCLES OF NATURAL RESOURCE MANAGEMENT

Scientific Advisor – CandSc (Economy), Assoc. Prof. Barun M. V.
Language Advisor – CandSc (Education), Assoc. Prof. Borzenko O. P.

The importance of issues of rationalization of natural resource management and modernization of the waste management system is explained, first of all, by the negative environmental impact on all components of the biosphere._Among the environmental risks, it is possible to highlight: depletion of natural resources, impoverishment of biological species and degradation of the general state of natural ecosystems.

The economy model of industrial production needs transformation in order to increase the efficiency of waste management and implementation the principles of sustainable economy development. Two economy models are considered: linear and circular, where the first has been used for a long time and today still has a predominant character.

Over time, the linear economy model, which is based on the "produce-use" principle, has proven to be inefficient, since the use of this business model leads to the formation of by-products – waste, which create environmental and economic losses for the state and entrepreneurs (Роледерс, 2021). Taking into account the trends in population growth and the need to increase production volumes, this will lead to increased pressure on the natural environment in the long term.

The collected waste is moved to storage sites, i.e. landfills, after which it is sent for disposal or the placement period is extended. The accumulation of waste at landfills causes harmful effects on the areas where they are located, fully altering the natural area: filtrate gets into groundwater and reservoirs, the fertility properties of soils decrease, heavy metals and other dangerous substances end up in the atmospheric air as a result of evaporation. In addition to its location, the landfill also has an impact on nearby areas.

The technological shortcomings of such waste management methods caused the need to implement a new system. The main principles for developing a new economy model began to be considered as early as the middle of the 20th century (Цюман & Зюзюн, 2023), when the gradual increase in the intensity of extraction and use of raw materials in industry drew attention to existing environmental risks.

Nowadays, this problem has become more relevant, since the experience gained over the past years has demonstrated the importance of maintaining the integrity of ecosystems in order to avoid an environmental disaster._Waste disposal is not an effective way to solve the problem of waste generation, so it is important to consider all possibilities for reducing its volumes.

The circular economy model is a production and consumption model that creates conditions for the use, rental, repair and recycling of selected raw materials and goods over a long period of time (European parlament, 2023). Thus, the product life cycle continues, which is positive in several ways:

1) reduction of natural resource extraction volumes,

2) reduction of technogenic load by optimizing production volumes,

3) recycling of sorted components of municipal solid waste and, as a result, less storage in landfills.

Based on this, it can be said that there is a complete dependence between the circular economy model and waste management logistics, since in order to ensure the functioning of this economy model, there is a need for targeted reform of the system and the development of waste management plans at national and regional levels.

Closed cycles of natural resource management can be created by rationalizing the extraction of pure raw materials and by recycling selected waste materials. An important role is played by the organization of activities related to the waste transportation, their separate sorting and determination of logistic routes for sending it to enterprises that recycle the selected type of raw materials. This system should work according to the following main principles (Gritsenko, Savchenko & Матвєєв, 2023):

- legislative control of relations in the field of waste management;
- formation of the concept of producer responsibility and ensuring conditions for its compliance;
- investment in the latest technologies for secondary recycling raw materials;
- implementation of waste transportation logistics covering the whole country;
- orientation towards the experience of other countries and creation of partnerships with enterprises within the country;
- taking into account the importance of developing infrastructure support for the waste management field when drawing up national and regional development strategies.

Based on the analysis of the circular economy model, its relationship with logistics and how they form the principles of closed cycles of natural resource management, it can be concluded that each component of the waste management organization process is an indivisible system. For its existence, it is necessary to plan in detail all stages of resource extraction, creation and use of products, taking into account all existing technological shortcomings and environmental risks.

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Orlova D. V.

OPTIMIZATION OF THE MUNICIPAL PLASTIC WASTE MANAGEMENT SYSTEM

Scientific Advisor – CandSc (Biology), Assoc. Prof. Prokopenko N. V.
Language Advisor – CandSc (Education), Assoc. Prof. Borzenko O. P.

In Ukraine, one of the most acute and urgent environmental problems is the problem of waste. For more efficient use of waste, separate collection and research of various options for their recycling/disposal are necessary.

Municipal solid waste (MSW) is waste that is generated during human life and activity and accumulates in residential buildings, institutions of social and cultural life, public, educational, medical, commercial and other institutions and has no further use at the place of its generation.

The separate collection system allows for the highest quality extraction of secondary raw materials from the MSW stream. This reduces the amount of waste to be buried, contributes to solve environmental and social problems and resource conservation, and increases the profitability of the MSW field.

The lack of an effective system for recycling (including a separate collection system) of municipal waste leads to Ukraine losing millions of tons of resource-valuable materials contained in waste every year, which could potentially be put into economic circulation in processed or recycled form. The development of separate collection and recycling of waste is an integral part of increasing the efficiency of natural resource use and the transition to a sustainable "green" economy.

According to the State Statistics Service of Ukraine, more than 15.5 billion tons of various wastes have accumulated in specially designated places, objects and on the territory of enterprises. Approximately 450 million tons of waste is generated annually, only 1/3 of which is utilized, recycled or burned, the rest else ends up in dumps and landfills.

The MSW volumes are constantly increasing, and the morphological composition is unstable and fluctuates depending on the season. Thus, MSW is a source of significant environmental danger.

The main problem is not even that a lot of garbage is thrown, polluting the environment, but that the country doesn't have a comprehensive waste management system. According to the State Statistics Service of Ukraine, the waste generation rate in Ukraine is on average 250-300 kilograms per year per person and has a tendency to increase.

The first step in optimizing the system is to reduce the volume of plastic waste at the stage of its production and consumption. This can be achieved by: promotion of multiple use; encouraging consumers to use reusable containers, bags and packaging; implementation of loyalty programs that offer discounts on reusable products.

The use of ecological alternatives takes into account the development and popularization of biodegradable materials that can reduce the burden on the environment, as well as supporting research in the field of new materials that can replace traditional plastic.

An effective waste separation system is key to the further recycling and disposal of plastic waste. Main directions: implementation of containers for separate collection; providing access to containers for collecting plastic, glass, paper and organic waste in public places; conducting information campaigns for the public, raising awareness of the importance of waste sorting and its impact on the environment (UNEP, 2024).

It is also worth mentioning here the experience of Norway, which takes a very responsible approach to the separate sorting and recycling of waste. For example, in Norway, there are special machines for collecting plastic bottles, when a customer buys a drink in a plastic bottle, he additionally pays a certain amount of money, which is added to the cost of the product, and then he can get this money by returning the bottles to the machine. There are also separate garbage bins near each house. Norwegians sort garbage into glass, plastic, paper/cardboard, food waste, and residual waste.

Containers differ in color. Collecting different types of waste in a single tank is strictly prohibited by law. Garbage removal from residential buildings is carried out centrally, but the removal fee is included in the amount of local fees.

Taking into account the EU experience, within the framework of the implementation of the "polluter pays" principle in Ukraine, it is advisable to carry out a number of reforms: to separate waste management for the population and the commercial sector as an independent service with a transparent payment structure; to start the phased implementation of payment for services depending on actual consumption; to move from setting tariffs and providing services in proportion to the area of premises to the payment system "pay for what you throw away"; to increase the environmental tax on waste disposal; to define a clear methodology for pricing services in the field of municipal solid waste management (European Union, 2024).

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Safronov V. Yu.

THE EVOLUTION OF NATURAL SCIENCES: A HISTORICAL OVERVIEW

Language Advisor – Asst. Prof. Chevychelova O. O.

The natural sciences encompass a wide range of scientific disciplines that explore the phenomena of the surrounding world, both in living and non-living nature. These disciplines are distinct from the humanities, which focus on human society, languages, and arts. The goal of this article is to provide an overview of the development of the natural sciences, tracing their historical emergence, classification, and the current trends in their evolution. The article investigates the major branches of natural sciences, their integration over time, and the growing interconnectedness between them.

Natural sciences have evolved through the centuries to cover an extensive array of scientific fields. The primary branches of natural sciences include astronomy, which studies the universe; physics, which explores the composition and structure of matter, and the phenomena in non-living nature; chemistry, focusing on the transformation and structure of substances; biology and ecology, which study living organisms and their ecosystems; earth sciences, encompassing geology, geography, and geophysics; and medicine, which addresses human health and disease. These branches form the foundation of the natural sciences and continue to evolve into specialized sub-disciplines as the scope of knowledge expands.

As scientific knowledge increases, natural sciences are undergoing a process of differentiation. New sub-disciplines and specialized fields are emerging as researchers delve deeper into specific aspects of nature. For example, physics itself is divided into mechanics, thermodynamics, optics, and electrodynamics, while chemistry has given rise to biochemistry and physical chemistry. The increasing depth of specialization makes it more challenging for specialists in one field to cross into other disciplines, leading to a more complex scientific landscape.

In contrast, there is also an ongoing trend of convergence in the natural sciences. Interdisciplinary fields, such as chemical physics, biophysics, and biogeochemistry, are forming at the intersections of different sciences, blending concepts and methods from various fields. This trend towards integration is a key feature of modern scientific progress, as it encourages collaboration between distinct disciplines to address complex questions and problems.

The emergence of natural sciences as a distinct area of study is often linked to the scientific revolution of the 17th century. Figures such as Francis Bacon, Johannes Kepler, Galileo Galilei, and Isaac Newton are credited with laying the foundation for modern scientific inquiry. Bacon's promotion of the experimental method helped shift the focus of knowledge from abstract theorization to empirical investigation. This period also saw the rise of modern science, which began to be viewed not only as a way to understand the natural world but also as a means to improve human well-being and control nature.

The 19th century saw a further evolution in the development of natural sciences, particularly with the rise of higher education and research institutions. Pioneers like Alexander von Humboldt and Justus von Liebig played a significant role in shaping the scientific landscape by combining research with academic institutions. Their work helped formalize the study of natural sciences and integrate scientific research with higher education, providing a solid foundation for future generations of scientists.

The natural sciences are currently classified into several broad categories, including physical, technical, and mathematical sciences (such as physics, astronomy, and computer science), chemical and biological sciences (including chemistry and biology), earth sciences (such as geology and geography), agricultural sciences, and medical sciences. Each of these fields employs specific methods and approaches, from empirical observation to theoretical modeling, to investigate natural phenomena.

A key characteristic of modern natural sciences is their increasing integration, which reflects the interdisciplinary nature of contemporary research. This integration is evident in the rise of concepts such as systematicity, self-organization, and global evolutionary principles, which are being applied across different scientific domains. Additionally, the interaction between natural sciences and the humanities is becoming more pronounced, fostering a more holistic approach to understanding both human and natural phenomena.

The development of natural sciences mirrors humanity's intellectual evolution, evolving from early mythological explanations of the world to the systematic, empirical approaches that define modern science. As scientific methods continue to advance, our understanding of the natural world expands, enabling technological advancements and improvements in public health, environmental sustainability, and various other areas.

In conclusion, the natural sciences have undergone significant development over the centuries, progressing from basic observations of nature to sophisticated, specialized fields of study. This evolution has been marked by both increasing specialization and greater integration across disciplines. The ongoing trend towards interdisciplinary research and the collaboration between natural sciences and the humanities promises to further enrich our understanding of the natural world and its complexities. As we continue to explore the mysteries of the universe, the development of natural sciences will remain essential in driving human progress and addressing the challenges of the modern world.

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Tkachov D.V.

THE ENERGY OF THE EARTH

Language Advisor – Senior Lecturer Ivanova I.L

In the grand tapestry of our planet, energy flows like an unseen thread, weaving together the intricate patterns of life, nature, and human existence. Imagine standing on a sun-kissed hill, the wind rustling through the trees, and the soft sound of a nearby stream trickling over stones. This is not just a peaceful scene; it is a vivid representation of the various forms of energy that fuel our world.

The power of SUN

Every morning, as the sun rises, it gifts us with an abundance of energy. This celestial body, a blazing ball of hydrogen and helium, sends rays of sunlight cascading down to Earth, nurturing all forms of life. Solar energy, in its most beautiful form, touches the leaves of trees, energizing them to produce oxygen and food through photosynthesis. It warms the soil, allowing seeds to sprout and grow into lush plants that blanket the earth.

As we harness this sun-drenched power, we find ourselves turning to solar panels glinting in the sunlight. They stand like silent sentinels, capturing sunlight and converting it into electricity. Families are able to power their homes, businesses, and lives with this clean, renewable energy source, all while reducing their carbon footprint.

Consider the example of a small town in California, which made a collective decision to transition to solar energy. With community funding and local government support, solar panels were installed on rooftops throughout the town. The result? A significant drop in energy bills for residents, a decrease in greenhouse gas emissions, and the town became a model for sustainable living. Not only did they save money, but they also inspired neighboring communities to follow suit, leading to a ripple effect of renewable energy adoption.

In countries like Germany, solar energy has transformed the energy landscape. The government incentivized solar power through feed-in tariffs, allowing individuals and businesses to sell excess electricity back to the grid. This policy not only spurred investment in solar technology but also contributed to a significant reduction in the country’s reliance on fossil fuels.

The power of WIND

But the sun is not alone in its quest to energize the planet. The wind, a powerful and unseen force, swirls across landscapes, from rolling plains to towering mountains. As it dances through the air, it carries with it the potential to generate energy. Picture a field dotted with wind turbines, their blades rotating gracefully as they harness the kinetic energy of the wind.

In Texas, known as the wind capital of the United States, thousands of wind turbines line the horizon. Here, the landscape is transformed into a wind farm, where the hum of machinery harmonizes with the natural sounds of the prairie. These turbines produce enough electricity to power millions of homes. In fact, on particularly windy days, Texas has been able to rely on wind energy for nearly half of its electricity needs.

Similarly, countries like Denmark have embraced wind energy wholeheartedly. In 2020, wind power accounted for about 47% of Denmark's total electricity consumption. This small country has become a leader in wind technology, exporting turbines and expertise worldwide. The Danish model demonstrates how investing in renewable energy can lead to energy independence and economic growth.

The power of WATER

Not far from these wind farms, a river rushes over rocks, its water sparkling in the sunlight. This is hydropower in action—a beautiful display of nature's energy. As the water flows, it turns turbines in dams, generating electricity that powers homes and industries. Hydropower is one of the oldest forms of renewable energy, dating back to ancient civilizations that harnessed rivers for irrigation and milling grain.

Imagine standing on the banks of the mighty Hoover Dam, a feat of engineering that stands as a testament to human ingenuity. Completed in 1936, the dam generates enough electricity to power 1.3 million homes in the southwestern United States. The immense reservoir created by the dam, Lake Mead, serves not only as a water supply but also as a recreational area, showcasing how hydropower can provide multiple benefits.

In Norway, over 95% of the country's electricity comes from hydropower. This reliance on clean energy allows Norway to maintain a low carbon footprint while supporting a high standard of living. The country exports surplus electricity to neighboring nations, turning its natural resources into a source of national pride and economic stability.

The power of FOSSIL FUELS

Yet, as we revel in the beauty of these renewable resources, we cannot overlook the shadows cast by fossil fuels. For over a century, coal, oil, and natural gas have powered our industrialized world. They have fueled our cars, heated our homes, and supported economic growth. However, this dependence comes with significant costs.

The burning of fossil fuels releases carbon dioxide and other harmful pollutants into the atmosphere, contributing to climate change and environmental degradation. Imagine a city shrouded in smog, where the air is thick with pollution, and the sun struggles to shine through. This stark reality serves as a reminder of the urgent need to transition to cleaner energy sources.

Consider the coal mining towns in the United States, where livelihoods depended on this resource for generations. As coal became less economically viable due to the rise of cleaner alternatives, many of these towns faced economic decline and job loss. The struggle of these communities highlights the need for a just transition—one that not only addresses climate change but also supports those impacted by the shift away from fossil fuels.

The NUCLEAR POWER

In the quest for energy, nuclear power emerges as a potent contender. Through the process of nuclear fission, energy is released when atomic nuclei are split apart. This process generates vast amounts of electricity without the carbon emissions associated with fossil fuels. Countries around the world have invested in nuclear power plants, seeing them as a way to meet growing energy demands while minimizing environmental impacts.

Yet, nuclear energy is not without its challenges. Concerns about radioactive waste and the potential for accidents have sparked debates about its safety and sustainability. Imagine a landscape dotted with cooling towers, a symbol of both human ingenuity and the risks that accompany powerful energy sources.

The Fukushima disaster in Japan in 2011 serves as a sobering reminder of the potential dangers of nuclear power. The event raised global awareness about nuclear safety, leading some countries to reconsider their energy policies. In contrast, countries like France have embraced nuclear energy, generating around 70% of their electricity from nuclear sources. France's commitment to nuclear power illustrates the complexity of energy choices, where safety, sustainability, and energy security must be balanced.

The FUTURE

As we stand at the crossroads of energy consumption, the path forward lies in embracing a blend of renewable resources. Picture a world where solar panels adorn rooftops, wind turbines dot the horizon, and hydropower flows through our rivers. Imagine communities working together to reduce energy consumption, invest in energy efficiency, and promote sustainable practices.

Emerging technologies, such as energy storage systems and smart grids, hold the key to a sustainable energy future. By harnessing the power of innovation, we can create a more resilient energy system that meets the needs of people while respecting the planet.

Conclusion

The energy of our planet is a story woven from the threads of nature, human ingenuity, and the challenges we face. As we journey through this landscape of energy, we discover not only the beauty of renewable resources but also the pressing need to change our ways. Together, we can harness the gifts of the sun, wind, water, and earth, paving the way for a cleaner, more sustainable future for generations to come.

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Trofimenko D.O.

PREVENTING FUTURE CHEMICAL ACCIDENTS: LESSONS FROM THE BHOPAL DISASTER

Language Advisor – Senior Lecturer Ivanova I.L.

The chemical industry is growing rapidly in the 21^{st} century: new laboratories are being built to test dangerous chemicals, and the largest factories are being established. Chemistry impacts almost every aspect of our lives, including household chemicals, paint, medicines, and agricultural chemicals (such as household poisons for rodent pests and others). However, the most active chemicals can be dangerous to humans. They may enter the lungs, be absorbed into the bloodstream, and cause dizziness, nausea, loss of coordination, or even death after evaporation.

New automated safety systems are now being used to prevent accidents. These systems are capable of stopping the release of chemical substances in the form of vapors and liquids through backup mechanisms, fuses, and more. However, at plants, technical malfunctions can still occur, such as failures in safety systems, issues in systems for mixing and synthesizing chemical compounds, or pipe breaks. Despite these advancements, the human factor remains the most dangerous and unpredictable element. It becomes particularly hazardous when caused by selfish motives.

As of 2024, perhaps the largest man-made disaster in human history, in terms of the number of victims, is the accident at the Union Carbide India Limited (UCIL) chemical plant, which occurred on December 3, 1984. The disaster is better known by the name of the city where it took place—Bhopal, in Madhya Pradesh State, Central India. UCIL was a subsidiary of the large American company Union Carbide Corporation (UCC), which produced pesticides for agriculture. The Indian market was one of the fastest-growing at the time, generating a huge demand for pesticides. UCIL relied on the reaction of methyl isocyanate (MIC) with other substances to manufacture pesticides, which required storing large quantities of MIC in tanks on the plant premises

One of the most well-known causes of the accident was the deliberate neglect to repair and upgrade safety systems (Grazia,1985). In the 1980s, the Indian pesticide market experienced a crisis that significantly reduced UCIL's revenue. To cut costs, an order was issued to reduce expenditures on equipment maintenance. As a result, by the time of the accident, many safety systems were either malfunctioning or had been completely deactivated. The heads of the working teams consistently downplayed safety violations and failed to address minor leaks, which ultimately contributed to the disaster.

However, the attitude of the workers was equally important. The Bhopal plant provided employment, so local residents (especially the families of UCIL workers) were strongly opposed to any investigations into the plant. Additionally, the workers had limited knowledge of the plant's systems, so even when they noticed equipment malfunctions, they were unable to fully understand the severity of the situation. They were also constantly reassured by their foremen that everything was fine.

The accident occurred at around 00:30 on the night of December 3. The MIC in the plant overheated in a tank, causing its temperature to rise to the boiling point of 39.5 °C. This led to an increase in pressure, which ruptured the emergency valve, causing MIC vapors to be released into the atmosphere. The steam began to come out of the flare tower, which was used to burn chemical vapors obtained as waste from the MIC reaction. Workers on the night shift tried to disperse the steam flow by directing jets of water, which were supposed to react with the MIC, but none of the jets reached the top of the tower. For about half an hour, toxic steam was released into the air. In total, 42 tons of MIC vapors were released. Surprisingly, the workers who were at the epicenter of the accident were not injured. There was a wind at the time, so all the MIC vapors were carried towards Bhopal.

The cloud covered the railway station and slums on the outskirts of Bhopal, which were only two kilometers away from the plant. Local residents of the slums often heard the training sirens of the UCIL plant and the fumes from the MIC waste incinerators, so even those who noticed the cloud did not pay much attention to it. Most people suffocated in their sleep.

Panic soon set in. Bhopal's hospitals became overcrowded, and doctors had no idea what they were dealing with. Within the next half hour, the authorities learned about the UCIL accident, and requested the formula of the substance released into the atmosphere. This information was crucial for providing first aid to the victims. However, UCIL initially refused to disclose the formula, citing it as a trade secret. It was only hours after the accident that UCIL management finally revealed the formula, but by then, precious hours had already been lost (Shrivastava, 1992).

On the morning of December 3, hours after the disaster, an intercity passenger train from Ujjain was approaching the Bhopal railway station. The drivers, conductors and passengers witnessed the tracks littered with hundreds of dead bodies of slum dwellers, including women and children. As the scale of the tragedy became evident, the train immediately left the station to remove people from the area affected by the poisonous substance.

As a result of the accident, approximately 3,000 residents died immediately, while 15,000 more succumbed in the following years due to exposure to the chemical. Around 500,000 people were exposed to the toxic substance. Within the first two weeks, 10,000 people died, and between 100,000 and 200,000 people suffered permanent injuries. At the time of the disaster, the official population of Bhopal was about 800,000.

To preserve its image, UCC still does not admit that the accident was caused by UCIL management's negligence, deliberate violation of safety regulations, inadequate personnel training and concealment of important details for selfish purposes. On its official website, in the "History" section, there is only one line dedicated to 1984, claiming that the accident was the result of sabotage (UCC Official Source, 2024). UCC remains a profitable chemical corporation to this day.

Summing up the above, it should be noted that, to prevent tragedies like Bhopal, a proactive and thorough approach to safety systems is essential. Frequent drills should be conducted to enhance employees' skills in responding to chemical accidents. Special attention must be given to the condition of equipment, and a spill response plan should be developed. This plan should outline actions to prevent or mitigate the consequences of a chemical vapor leak, such as using water pumps to reduce gas dispersion or grounding tanks containing hazardous substances.

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ДЛЯ НОТАТОК

Наукове видання СТУДЕНТСТВО. НАУКА. ІНОЗЕМНА МОВА

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ТУРИЗМ, ГОТЕЛЬНО-РЕСТОРАННА СПРАВА
ПСИХОЛОГІЯ ТА ЗДОРОВ’Я
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Адреса редакції: 61002, м. Харків, вул. Ярослава Мудрого, 25, тел. 752-88-87