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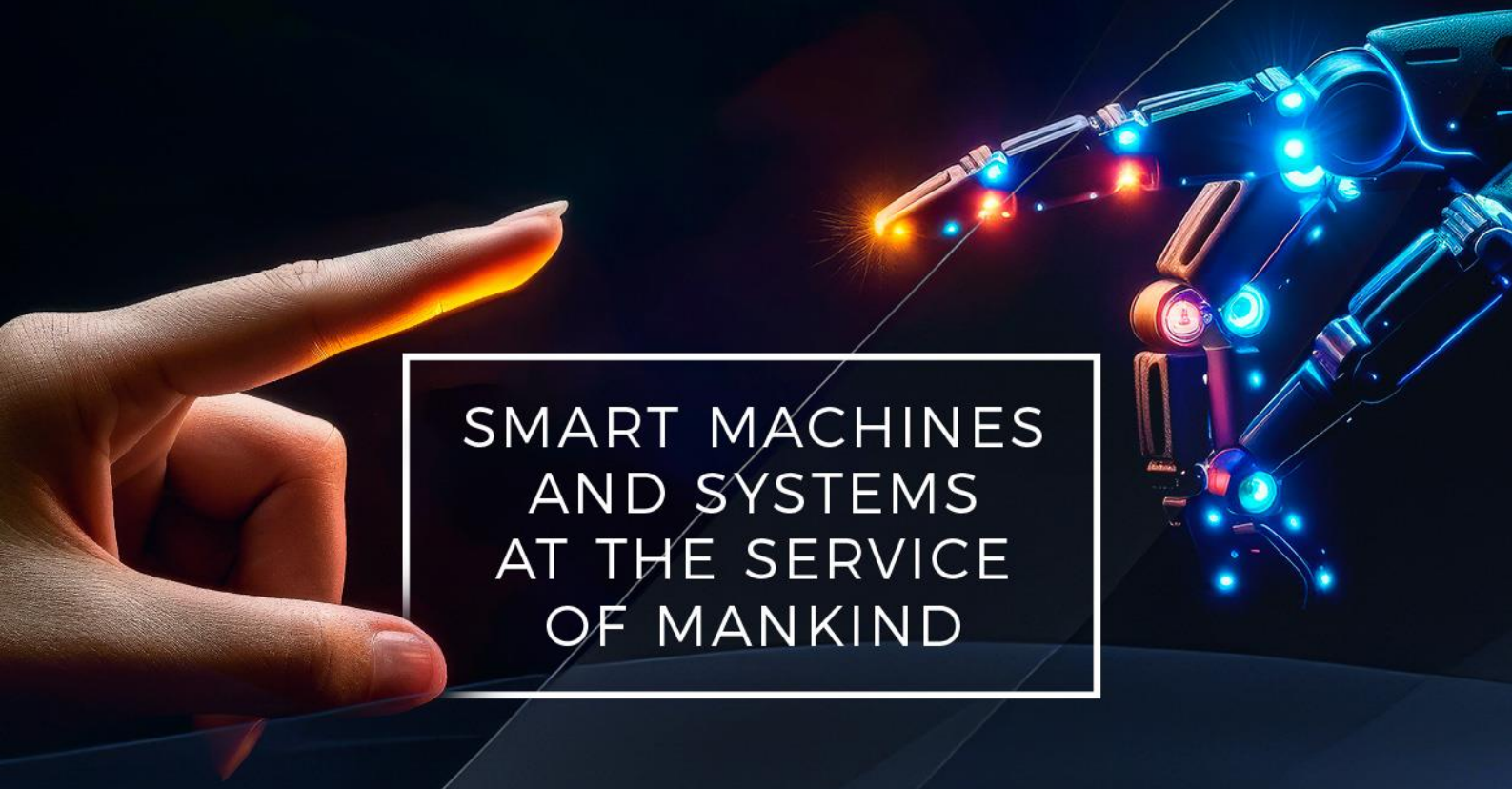

SMART MACHINES AND SYSTEMS AT THE SERVICE OF MANKIND

MONOGRAPH

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This book explores the transformative potential of smart technologies, digital advancements, and artificial intelligence (AI) across multiple domains, emphasizing their roles in urban mobility, sustainable development, financial innovation, and modern management practices. It highlights global perspectives, drawing on case studies and research from experts in various fields to address challenges and opportunities in the digital era. *Chapter 1* delves into the integration of smart technologies to enhance urban mobility. Topics include revolutionary approaches to smart parking, the development of infrastructure for autonomous vehicles in Pakistan, and hybrid technology management for post-war infrastructure reconstruction. *Chapter 2* focuses on digital technologies' contribution to sustainable development, exploring AI's role in resource optimization, international collaboration in AI for sustainability, and leveraging digital solutions to address environmental challenges like forest conservation and green logistics. *Chapter 3* examines the impact of smart machines and AI in specialized sectors such as finance, accounting, and auditing. It also addresses strategies for managing resistance to AI adoption in organizational settings, ensuring a smooth transition to advanced technological ecosystems. *Chapter 4* investigates the innovation and management landscape shaped by digital transformation. Discussions include industry-specific solutions in the era of Industry 4.0, AI's integration into business process optimization, and its role in enhancing digital branding of regions. This comprehensive work offers valuable insights for academics, practitioners, and policymakers aiming to harness the potential of digital technologies for progress and resilience in a rapidly evolving global environment.

Keywords: smart technologies, urban mobility, artificial intelligence, sustainability, digital transformation, green logistics, innovation management, Industry 4.0, autonomous vehicles, smart machines, resource optimization, digital branding.

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CONTENT

Chapter 3 Smart machines and artificial intelligence

Chapter 4 Innovation and Management in the Age of Digital Transformation

INTRODUCTION

In the digital age, major industries, cities and societies are rapidly evolving, pressured by technologies transforming the way we live, work and interact. In this monograph, the authors examine the far-reaching impact of these developments and their role in driving urban mobility, sustainability, artificial intelligence and innovation management. By treating these integrated themes, the book provides a comprehensive picture of how technological progress impacts the contemporary world as it creates the basis for a more sustainable and innovative future.

Smart technologies are reshaping how we move through cities now and in the future. Smart parking solutions and advanced reversible charging systems are helping solve issues such as traffic congestion and environmental impact and encouraging the mass adoption of electric vehicles. In addition, if autonomous vehicle technology is to achieve its transformative potential, it will need significant development of supporting infrastructure in order to be safe and efficient. Also, managing infrastructural projects, especially in post-conflict reconstruction period, clearly demonstrates the advantages of smart technologies in running operations and rebuilding critical systems. Together, these advancements signal that smart technologies have the potential to produce more intelligent, more intelligent, more resilient, and sustainable urban ecosystems.

Digital technologies are equally important in enabling sustainable development concerning the global challenge of resource scarcity. With a rising percentage of the population being served by economic growth and more people demanding economic growth, artificial intelligence represents a powerful tool for optimizing resource use and achieving greater efficiency and less waste. With the help of AI, companies and governments can make decisions that are more data-centric and aligned to sustainability goals that help manage finite resources responsibly. AI development requires international cooperation to close knowledge gaps and ensure the availability of new technology. Beyond resource optimization in conservation, digital tools are being exploited in environmental conservation, e.g., in forest management where innovative legal and operational frameworks are making a difference. Additionally, the use of the Internet of Things (IoT) in green logistics and marketing is a practical demonstration of the digital transformation that combines economic growth with enterprise environmental priority to maintain profitability and ecology balance.

Artificial intelligence and smart machine technologies are changing industries by making them more efficient, resilient and adaptable. For example, in the financial sector, AI is helping make smarter systems that ensure better operational security and achieve operational efficiency through complex processes. It's changing the anatomy of traditional financial models by automating tasks and giving predictive insights to make them more resistant to uncertainty. Just like that, AI is also changing the accounting and auditing landscape with the help of increased data accuracy, higher level of transparency and more consequential decision-making. While the benefits of AI are clear, many factors hinder its adoption, such as the need to address human and organizational concerns effectively. Overcoming these challenges allows industries to realize the full potential of AI and will yield the fruits of growth and innovation.

In the digital age, innovation and management practices are being redefined at the fundamental level. Putting Industry 4.0 opportunities to good use, businesses are finding ways to optimize, grow and stay competitive. This transformation is centered on artificial intelligence, which permits organizations to

optimize workflows, better plan, and assist creativity. Moreover, digital branding based on AI is changing how regions and territories build their image. Crafting compelling digital narratives can make these regions appeal to investment and increase economic development. These advances underlie the transformative nature of technology to define business strategy and regional and national identities.
This monograph shows that digital transformation is more than just a technological shift; it catalyzes societal, environmental, and economic change. If we adopt these innovations, stakeholders in different sectors can tackle some of our time's most significant challenges — from congestion and resource scarcity to organizational cynicism and environmental destruction. As a guide and source of inspiration, this book provides readers with the know-how and strategies required for a complex digital age. With the help of smart technologies and digital solutions, we can achieve a more sustainable, resilient, and innovative future.

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Chapter 1. Smart technologies and urban mobility

SMART PARKING AND ADVANCED REVERSIBLE CHARGING: REVOLUTIONIZING URBAN MOBILITY

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Abstract

An increasing challenge in mobility management is the problem of urbanization, where parking inefficiencies and integrating electric vehicles in existing grids become a complex problem. The solution proposed in this manuscript for the SPARC (Smart Parking and Advanced Reversible Charging) project is an innovative combination of intelligent parking systems and bidirectional EV charging technology. It also provides the specific goals of this SPARC project and delineates the main benefits of SPARC project goals, which mainly describe the reduction of urban congestion, improvements of grid stability, and encouragement of sustainable energy use. The project includes real-time parking management, dynamic pricing models and a suitable user-friendly app design. While the number of electric vehicles on the roads is anticipated to increase as a result of the project, as is the number of charging stations, the primary projected outcomes involve environmental and social improvements, including reduced CO2 emissions, improvements to the urban environment, and

increased adoption of electric vehicles. The authors position SPARC as a scalable model of sustainable urban development that tackles problems of a social and technological nature.

Keywords: *Smart parking, bi-directional EV charging, urban sustainability, vehicle-to-grid (V2G), decentralized energy, smart mobility.*

Introduction

Due to urbanization, parking inefficiencies and traffic congestion have increased the adverse effects on environmental quality and urban livability. Current parking systems yield higher levels of vehicle emissions and a generally lower quality of life. As a result, smart parking systems have come to the forefront of the solution. IoT-powered parking space monitoring systems monitor parking space availability in real-time, reducing the time a driver spends looking for a parking space and reducing traffic congestion and associated emissions.

According to Allam and Newman (2021), IoT has a significant potential role in facilitating efficient parking and ensuring environmental sustainability in urban governance.

As the number of electric vehicles (EVs) increases, urban energy management poses challenges and opportunities for growth. Not only do EVs draw power from the grid, but they can also supply power back into the grid, known as bi-directional charging, often referred to as V2G (Vehicle to Grid – technical term). It means bi-directional energy flow, improving grid stability and energy efficiency. An extensive analysis of several bi-directional converter topologies and control techniques is provided by Rana et al. (2024), with a strong emphasis on their utilization for power flow optimization between vehicles and the grid.

Smart parking systems integrated with two-way EV charging infrastructure represent a promising approach to sustainable urban mobility. This integration enables apt parking management, which, in turn, helps maintain the energy grid through V2G interactions. According to Allam and Newman (2021), smart parking solutions can help decrease greenhouse gas emissions by enabling parking slots to be found sooner. In addition, bidirectional EV charging stations can significantly improve grid resilience, as they can serve as decentralized energy resources for them.

However, the development of these integrated systems is not a simple problem. There are quite a few technological hurdles to ensure that all components work well together. Furthermore, regulatory frameworks must adapt to the dual character of EVs both as consumers and suppliers of energy. Finally, public acceptance is another critical factor, such that effective means to get as many people to trust and adopt these new technologies needs to be developed. In addition, the project involves the processing of information by several organizations – restricting the use of information by one organization is not practical. This requires addressing data privacy and security concerns in the data processing system.

Smart parking systems, together with bidirectional EV charging, are promising for more sustainable movement of people and energy. Some existing research foundation is provided; however, more research is needed to examine the practical implementation of these integrated systems, the resulting long-term impacts, and strategies to overcome associated challenges. As a pioneer in this emerging field, the SPARC project piloted innovative solutions to urban mobility and energy sustainability

questions. Project piloted innovative solutions to the dual questions of urban mobility and energy sustainability.

Research Objectives

The vision of the SPARC project is to leverage innovative solutions to address critical urban mobility challenges with both functionality and sustainability. The primary purpose is to design real-time parking slot detection systems that have been built based on advanced sensor technology and data analytics. Such systems significantly reduce the time spent looking for parking spaces by providing accurate, up-to-date information on parking availability with free spaces, thereby reducing traffic congestion and related emissions. This efficiency in finding parking spaces helps eliminate urban congestion and improve the quality of life in densely populated areas.

Integrating bi-directional EV chargers is another key goal, as these chargers enable new V2G operations. EVs with these chargers, while also consumers, are now dynamic energy suppliers to the grid. Bi-directional charging systems such as these aid in balancing energy consumption during peak hours, strengthening the network, and making the best possible use of renewable energy sources. The integration of EVs as a part of a decentralized energy system is one that enables a more resilient, sustainable energy infrastructure.

The project also creates a seamless bridge between public transport and urban mobility by strategically placing parking hubs near transit stations. These parking hubs will enable public transport by offering solutions to reduce last-mile dependency on private vehicles. This initiative contributes positively to sustainable travel behavior, lessens urban load traffic density, and encourages efficiency in land use.

Lastly, the SPARC project aims to increase urban sustainability by handling important environmental issues. These advanced systems can help reduce urban noise levels, air pollution and CO2 emissions. These efforts also align with broader global sustainability goals and reflect the commitment to making the project one that helps improve cleaner, quieter, and more livable urban spaces. These objectives highlight SPARC's integrated approach to transforming urban mobility and energy management.

Methodology

The SPARC project addresses the problem of urban mobility and energy management, revolutionizing the problem via a comprehensive, multi-phase approach. First, pilot implementation of smart parking systems is conducted in Riga, Tartu, Vilnius and Poznań. In this phase of the project, 50 parking spots will be equipped with state-of-the-art bi- directional chargers to study the core technologies of this project in a real-world deployment. A well-thought-out mobile application is central to the user experience, delivering real-time information regarding parking availability and charging status.

The project succeeds through collaboration with key stakeholders, such as municipalities, energy providers and private operators. SPARC leverages partnerships to ensure that its solutions are both scalable and adaptable to the varied urban settings they will operate in. The project also uses advanced data analytics to optimize the parking and charging operations. User feedback and energy consumption patterns are used for continuous improvement to increase system efficiencies and user satisfaction.

Several innovative technological advancements are at the heart of SPARC's framework. Parking solutions are often intelligent solutions that give live parking availability updates delivered by sensors and algorithms, ultimately reducing urban congestion and emissions. Bi-direction charging technology turns electric vehicles into mobile energy units and can supply power back to the grid during peak demand. The dynamic pricing models complement these innovations by rewarding financial incentives for reverse charging that encourage higher user participation.

The project also demonstrates mobile integration through a user-friendly app that simplifies parking and charging processes. Along with convenience, widespread adoption of SPARC's solutions is further enabled via this integration. As an integrated system, these strategies and technologies combined put SPARC at the forefront of initiatives working towards creating smarter, greener, and more sustainable urban systems.

Results

To transform urban mobility and energy systems, the SPARC project anticipates considerable technological, environmental, societal and economic benefits. Technologically, the project leads to the deployment of a complete operational parking and charging management system with the integration of smart technologies that enhance parking and charging flow. With bi-direction energy flow enabled by bi-direction electric vehicle (EV) chargers, this system expects to improve the grid stability significantly by incorporating the decentralized energy storage, helping to provide power back to the grid during the peak demand periods, thereby creating a more robust and equal energy infrastructure (Rocco et al., 2023).

From an environmental perspective, the SPARC project has the potential to significantly contribute to reducing urban CO2 emissions and noise pollution. According to Connecticut Electric Vehicle Council Executive Director Richard Just, the more electric vehicles (EVs) that are added to the public grid, and the faster users transition away from internal combustion engine vehicles, emissions figures are forecast to decline as a result: 'Of course, in terms of providing cleaner air or lower noise levels in some of these urban areas where car congestion is an issue, that is great,' said Mr Just. Furthermore, the project aims to promote greater adoption of renewable energy in urban areas by using EVs as energy storage systems, allowing for smarter use of solar, wind, or other renewable resources in city grids (EU Green Deal and Sustainable Urban Mobility Guidelines, 2024).

The SPARC project could also improve work-life balance at a societal level by reducing the time drivers spend looking for parking spots. By offering real-time parking availability and optimized parking management, drivers will spend less time sitting in their cars, quickly becoming less frustrated as they find free time to enjoy on the way. In addition, the project supports greener transportation practices since the proactive acceptance of EVs and the incorporation of green energy sources prompt citizens to acquire more eco-friendly travel practices, consequently developing the culture of greenery in urban communities (Patel, 2024).

From an economic perspective, the SPARC project is expected to create new income-generating sources for municipalities and the private sector. Cities can begin to generate income from parking fees and energy transactions as vehicles feed energy back into the grid by deploying smart parking systems and bi-directional EV chargers. It becomes beneficial for local governments that want to raise

their revenues. Furthermore, the project promises to lower the cost of energy distribution for providers. Achieving a greater balance between demand and supply helps reduce the necessity for costly upgrades to the infrastructure and a more efficient energy grid altogether, resulting in substantial long-term economic advantages (McKinsey & Company, 2022).

However, to fully realize the benefits of the SPARC project, some challenges need to be addressed. A significant challenge is integrating the technology, particularly fitting what are often incompatible systems such as parking management software, EV chargers, and the energy grid. It will need to be countered by adopting standardized communication protocols, which will help to reduce disruption and ensure smooth operation (Allam & Newman, 2021). Furthermore, regulatory alignment is essential for the project. To complete it, policymakers must work closely together to help comply with local laws and adopt devious solutions. It will require traversing regulatory frameworks as well as parallelizing the project's goals with those of larger-scale urban development plans.

Another main challenge is public acceptance. Overcoming this will require comprehensive education campaigns that will rebuild trust and demonstrate the environmental and societal benefits of the project. When the public is engaged early on, and the new system is described in clear, accessible detail, resistance to the new system will be lower and greater citizen adoption will be more common. However, serious data privacy concerns need to be carefully managed because the project is very digital and based on user data. Protecting user information with robust security measures is necessary to build trust in the system and its long-term success (Rana et al., 2024).

The promise of SPARC as a technology, environmental, societal, and economic force could be enormous, but it will also require overcoming the integration of this technology, resolving the gap between regulations, aligning public opinion and buying, and ensuring the privacy and confidentiality of data. Proactively mitigating these risks, the project will usher in a new era of urban mobility and energy systems and help us create more sustainable, efficient, and liveable cities of the future.

The SPARC project has significantly addressed critical urban challenges of sustainable mobility and energy efficiency through a structured, innovative approach. Each figure presents a complete picture of the project's development and implementation in achieving the assigned objective.

Fig. 1 is the first step to implementing the project's vision. The mission reflects the Integrated Mission to make a smarter, greener city alive using advanced technologies and sustainable practices. This vision stands out as the basis of all actions and brings together stakeholders (municipalities, energy providers and other organizations in the public) around a common objective. The project articulates the mission that it serves to ensure that every effort is consonant with its long-term aims.

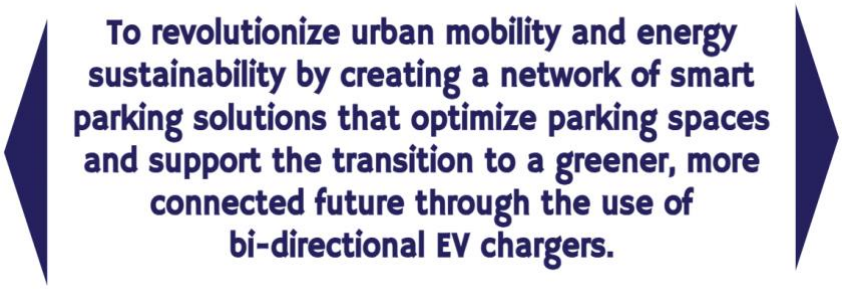

Fig. 1. The SPARC project mission statement. *Source: authors development*

As depicted in Fig. 2, SPARC's urban mobility solution focuses at its heart. The problems of today's cities – traffic congestion, inefficient parking systems, high energy demand – are juxtaposed with SPARC's bespoke solutions. For example, the project's parking detection systems and bi-directional EV charging technology directly solve these inefficiencies and open the door for smarter urban living. The project frames the problem and solution side by side to communicate its value proposition to stakeholders and beneficiaries.

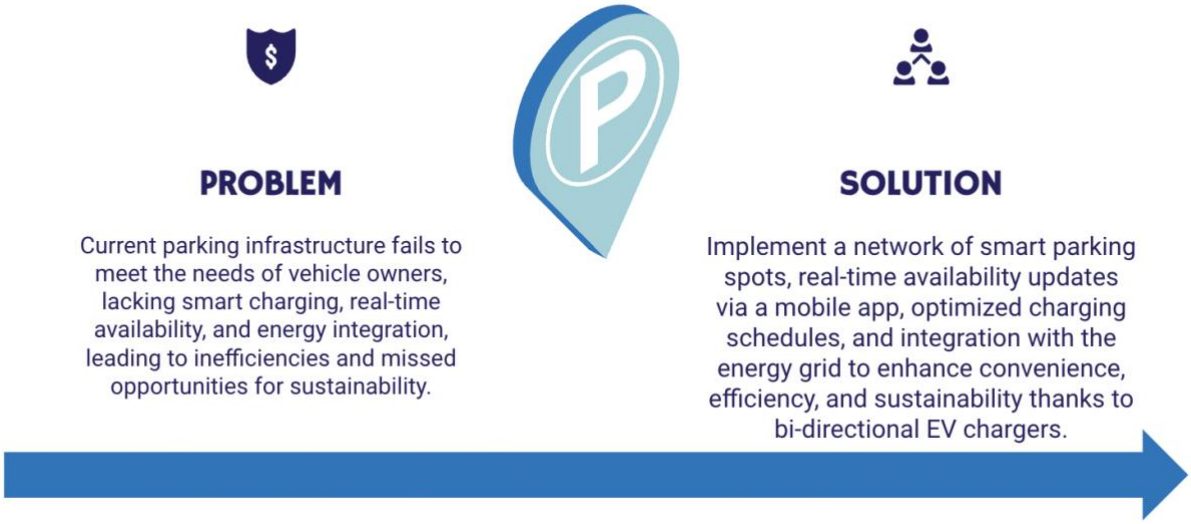

Fig. 2. Problem vs. Solution. *Source: authors development*

Fig. 3 shows a careful unfolding of the phased implementation of SPARC. Steps of Main Project Implementation. The step-by-step approach aims to achieve this goal by starting with pilot programs in cities such as Riga, Tartu, Vilnius, and Poznań, where 50 parking spots will be furnished with bidirectional chargers. After the pilot phase, we will refine the insights to scale our technology and strategies for broader applications. The phases advance on top of one another, showing dedication to continuous improvement as well as efficient resource utilization.

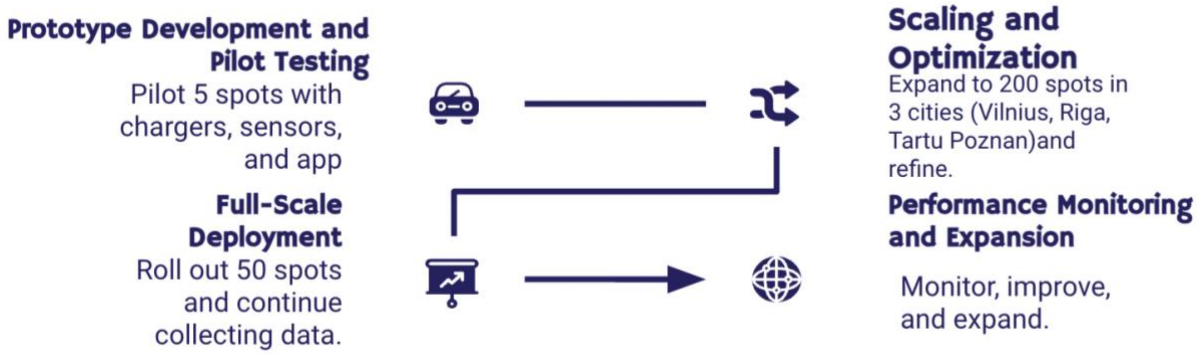

Fig. 3. Main project implementation steps. *Source: authors development*

The main technological and operational breakthroughs of the SPARC Project are described in Fig. 4. Some of these features involve intelligent parking solutions based on sensors and algorithms, allowing

for real-time information about available parking. EV charging is configured to allow two-way charging, enabling vehicles to be mobile energy storage units and helping maintain grid stability during demand peaks. Moreover, a user-friendly mobile application facilitates parking and charging procedures, and comfort can be achieved. Taken together these features represent how SPARC uses innovation to solve particular urban problems.

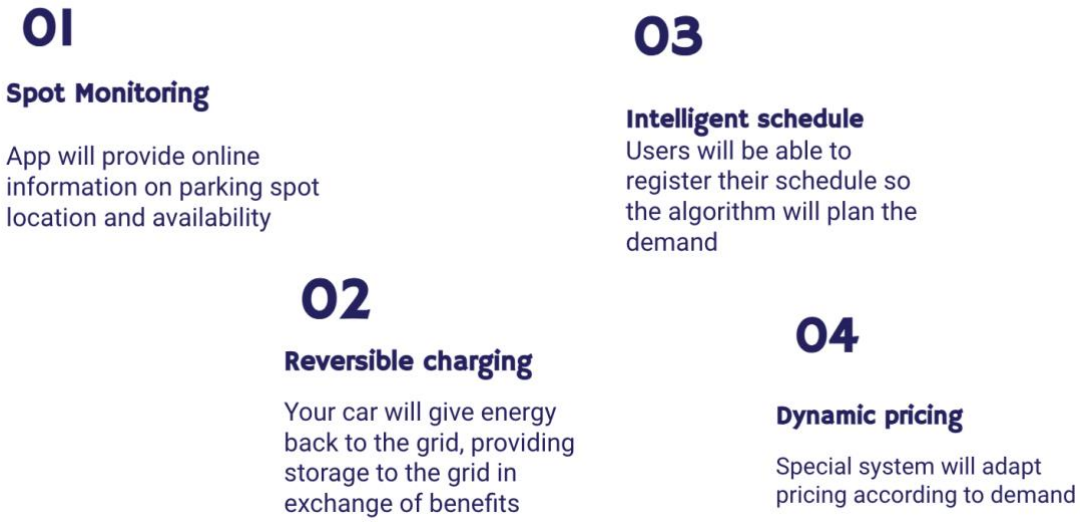

Fig. 4. The Key Features of the SPARC project. *Source: authors development*

The goals of the SPARC Project are specific, measurable, achievable, relevant and time-bound (Fig. 5). They are to minimize urban pollution and CO_2 emissions, increase energy efficiency through vehicle-to-grid operations, and reduce the time drivers spend searching for parking spaces. With clear and achievable goals set, SPARC provides a framework for how it has made an impact and how it will continue in its direction.

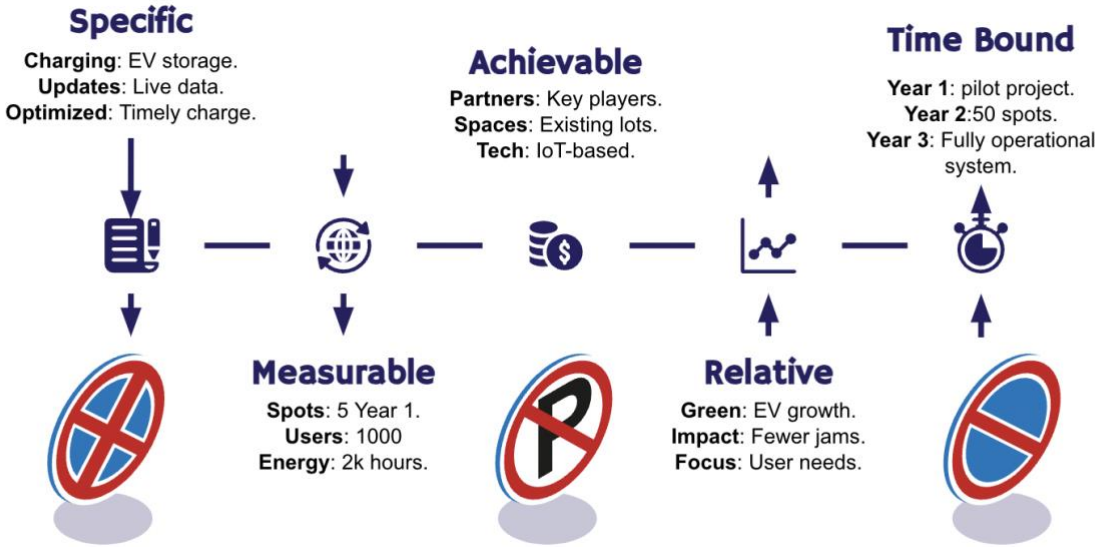

Fig. 5. The smart goals of the SPARC project. *Source: authors development*

The project is characterized by inclusivity, where stakeholder engagement is key (Fig. 6). The SPARC Project Target Group illustrates that key beneficiaries include urban commuters, municipalities, energy suppliers and private operators. By meeting the needs of these various groups, SPARC's solutions are equitable and have a wide impact, thereby creating more buy-in and collaboration amongst stakeholders.

Fig. 6. The target group of the SPARC project. *Source: authors development*

Fig. 7 captures the comprehensive nature of SPARC. It describes the SPARC Project, which combines technology, strategic scheduling, and sustainability into one cohesive framework. The biggest takeaway is how it embodies this project in a holistic sense, from parking systems to dynamic pricing models that incentivize user participation. It is a summary of the multifaceted project to reshape urban mobility.

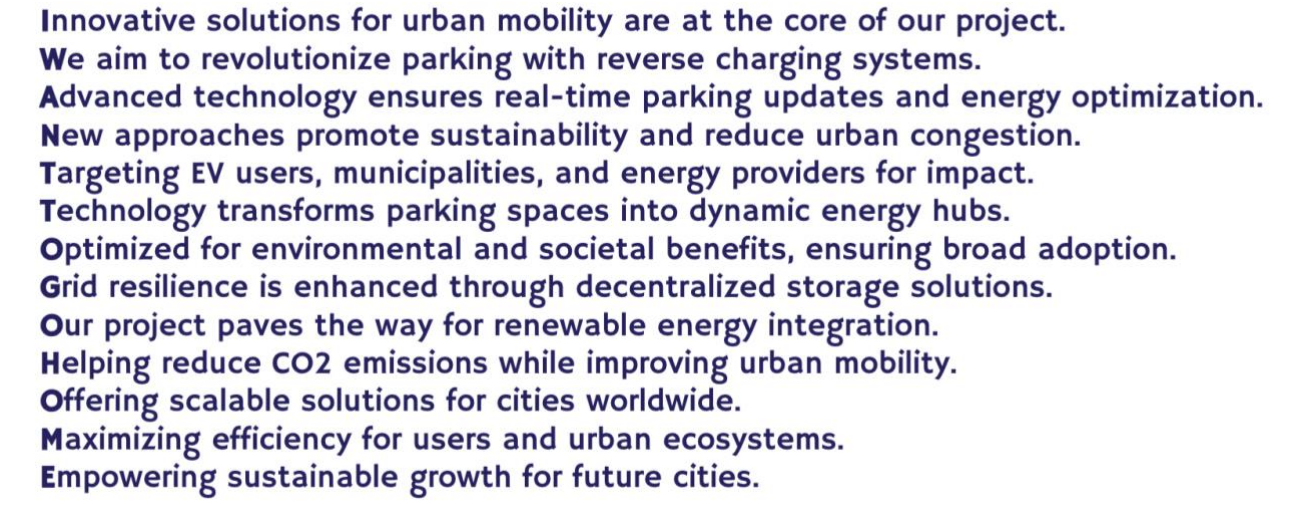

Fig. 7. Description of the SPARC project. *Source: authors development*

In Fig. 8, the focus is on financial transparency and efficiency - the allocation of $3M in a 3-Year Project. This $3 million project budget breakdown shows how resources are used wisely, considering all the research, pilot implementation and scaling operations. This allocation shows SPARC's accountability and strategic approach to doing the most with the least available resources.

Fig. 8. Budget Allocation for 3-Year Project ($3M). *Source: authors development*

Fig. 9 summarizes the tangible achievements of the project. Among these are reduced urban congestion, increased electric car adoption, and more potent energy grid stability. These outcomes are proof of the project's success in reaching its goals and returning positive value to stakeholders.

Fig. 9. Outcomes of the SPARC project. *Source: authors development*

Moreover, Fig. 10 explores the more significant societal and environmental impacts of the SPARC project. SPARC helps create more sustainable and livable cities by reducing urban emissions, integrating public transport and enhancing urban living standards. This demonstrates how the project's impacts contribute to dealing with the problems of world urbanization.

Fig. 10. Impacts of the SPARC project. *Source: authors development*

Fig. 11. shows the key innovations of the SPARC project, which make the SPARC project so revolutionary. Dynamic pricing models, mobile integration in real-time, and collaboration with stakeholders resolve the immediate problems but also transpose a replicable framework for other cities and regions.

Fig. 11. Type components or the most important innovations of the SPARC project.
Source: authors development

Finally, the SPARC project is a complete and scalable model for sustainable urban development. It has successfully tackled the challenges of urban mobility and energy efficiency through a well-defined mission, defined innovation solutions and measurable results. The story they tell together illustrates how SPARC can transform its potential into building smarter and greener cities for the future.

Discussion

The SPARC project findings show that it significantly addresses urban challenges while utilizing innovative technologies and sustainable strategies. The project's smart parking system and bidirectional electric vehicle (EV) charging integration are practical and scalable approaches to solving urban mobility and energy management problems. Finally, the broader implications of SPARC's initiatives, the alignment with global sustainability goals, potential improvement areas, and future research are discussed.

SPARC's vision is holistic in its own nature, as demonstrated by its mission statement and implementation. Intelligent parking systems help reduce time spent looking for a parking space, significantly contributing to urban congestion and associated emissions. Later, the project's emphasis on real-time data and mobile app connectivity represents the form of being valuable in promoting public adoption and operational efficiency through user-centric design. These aspects are consistent with more considerable smart city efforts to improve city living while minimizing environmental consequences.

It is an advancement in the state of the art of energy management in a bidirectional EV charging setting. The project is designed to help evolve electric vehicles into dynamic energy storage units that enable vehicle-to-grid (V2G) operations. This technology enables the adoption of renewable energy sources and stabilizes energy demand during peak periods. Moreover, by extending the profit potential for dynamic pricing models to encourage user participation, this strategy also forms a win-win dynamic between urban commuters and energy providers.

Another important component of this SPARC is how it fits with global sustainability and urbanization. SPARC promotes unbundling from private car dependence and reduces emissions and urban noise pollution by integrating public transportation with strategically located parking hubs. Resonating with the United Nations' Sustainable Development Goals (SDGs), it has strong implications for goals around sustainable cities and communities (SDG 11) and affordable and clean energy (SDG 7).

Collaboration with stakeholders has been a significant success factor of the project. SPARC's solutions involve municipalities, energy providers, and private operators, which ensures that they are socially, economically, and technically viable. This project's collaborative model could be a blueprint for other urban centers with similar challenges. However, continuously engaging stakeholders across various regions remains challenging, especially considering varying regulatory frameworks and market dynamics.

Although some outcomes of the project were very significant, there are also some limitations that need discussion as well. The pilot implementation of the platform was implemented in select cities, which made it difficult to generalize the findings when studying other complex urban contexts. Adapting the project to cover cities with varying infrastructure, demographics and regulatory contexts would yield important insights about the breadth of SPARC's solutions. Moreover, the dependency on cutting-edge technologies and real-time data requires strong digital infrastructure that is not easily available everywhere. Further research should seek to improve the accessibility and affordability of these technologies.

The SPARC project also opens up future exploration. For example, the environmental impact of the bidirectional charging system could be further enhanced by more seamlessly including renewable

energy sources with the system. Similarly, we could also explore the long-term economic and social impact of dynamic pricing models and their adoption by different types of user groups and understand their limitations and scalability.

In summary, the SPARC project is a cutting-edge urban development model. Its innovative solutions address key issues related to urban mobility and energy management and promote teamwork among stakeholders. Even though there are some limitations, the project's outcomes show its potential to transform and create strong foundations for other improvements to make smarter and more sustainable cities.

Conclusions

SPARC project is a forward-looking approach to solving critical urban challenges around mobility, sustainability and energy management. Through the project, an innovative approach has been demonstrated by integrating smart technologies that demonstrate their potential for creating an efficient, environmentally friendly, and user-centered urban environment. The conclusions reached by this research point out the project's contributions to urban planning, conformity to global sustainability guidelines, and potential as a scalable model of future implementations.

At its heart, SPARC robustly brings together intelligent parking systems with bi-directional EV charging and information management in real-time to effectively deal with the inefficiencies of the traditional urban mobility system. By minimizing the time parked vehicles spend searching for free parking spaces, smart parking solutions greatly reduce congestion and, therefore, emissions. The project has integrated these systems with an easy-to-use mobile app, an integration that increases accessibility and convenience and will encourage general use.

A crucial innovation is the introduction of bi-directional EV charging, turning electric vehicles into active components in energy management regimes. On its own, this approach does two things: it stabilizes energy demand during peak periods and helps enable the transition to renewable energy sources. In order to highlight the feasibility of V2G applications on an economic level to encourage vehicle-to-grid operations, dynamic pricing models are used.

In addition, the SPARCproject focuses on integrating public transport, and the sustainability aspect helps apply its impact broadly. The initiative places parking hubs near transit stations, thereby enticing public transportation use and reducing the dependence on private vehicles, which goes a long way toward creating a cleaner and quieter urban environment. In this context, our efforts are consistent with the United Nations' SDGs, specifically regarding sustainable cities and clean energy.

The project has been successful due to close collaboration among municipalities, energy providers, and private operators. This multi-stakeholder approach will guarantee that the solutions developed are technically robust, economically feasible, and socially inclusive. The model presented by SPARC provides a valuable case study for replicating similar initiatives in other cities.

Whilst successful, the SPARC project also exposes the difficulties of bringing advanced technologies to varied urban environments. Although the pilot program's plan to test specific cities makes sense to demonstrate the feasibility of its solutions, the results need to be tested more widely in different urban and regulatory settings. Also, the fact that it depends on digital infrastructure and real-time data

management might expose cities to weak technological capability. To scale the project's solutions globally, we must address these barriers.

Finally, the SPARC project illustrates how cutting-edge technologies and strategic collaborations can solve problems in cities. Citizens will respond positively to the initiative as a number of its achievements in cutting and reducing congestion, boosting energy efficiency and fostering sustainable mobility can serve as a reference model for other cities that need to modernize their urban systems. Though there are some limitations left, what SPARC has taught us is worth learning for future research and development. Cities around the world can build on the project's successes and engage its challenges to adopt similar approaches to develop smarter and more sustainable urban spaces. This study reconfirms the transformative nature of incorporating intelligent technologies into urban planning and will encourage other foreseeable innovations and partnerships to achieve global sustainability targets.

Recommendations

From the SPARC project's findings and conclusions, several key recommendations for future initiatives aimed at urban mobility and energy management are outlined. These suggestions take advantage of the project's success while trying to solve the problems encountered while executing it. However, they also provide a framework to scale and impact smart parking and bidirectional EV charging systems so cities can more easily take advantage of them.

It is suggested that the integration between smart parking systems and bi-directional EV charging is expanded to more urban areas after the pilot city programs. Riga, Tartu, Vilnius and Poznań were able to provide valuable insights, but wider implementation across a range of urban environments (especially in developing cities) could allow for a better understanding of how technologically scalable these technologies are and where they could be implemented most widely and best. It could further expand on the challenges faced in different regions, addressing infrastructure readiness, regulatory frameworks, public acceptance, etc. so that solutions can be tailored for these regions.

Besides geographical expansion, the SPARC project should promote collaboration with local authorities and stakeholders to bypass administrative and regulatory hurdles. The role of municipal governments in urban space planning and infrastructure development is very important and cannot exist without the support of local authorities who would regulate the implementation of intelligent technologies. Through stronger partnerships with local governments, energy providers, and private operators, SPARC can ensure its solutions are technically feasible within local policies, regulations, and urban development goals. Getting stakeholder engagement early in the process and continuously getting it will provide a fertile ground for innovation that is also more conducive to it.

Secondly, a second key recommendation is to develop mobile applications and digital interfaces for supporting smart parking and V2G systems. The SPARC project's mobile app successfully provides real-time updates about parking availability and charging status. However, additional features and functionalities could help increase the engagement and satisfaction of the user. For example, more advanced data analytic functions like predictive algorithms for parking space availability can enhance user experience. Also, further integrating the app with public transit services may add to the incentives to use non-polluted transport modes, thus reducing urban traffic and emissions.

In addition, the dynamic pricing models proposed in the SPARC project present a potential route for promoting reverse charging and consequently improving energy supply. Extending these models to include more granular pricing strategies could add additional economic price signals for users to join in vehicle-to-grid (V2G) operations. The system could adjust its pricing based on power demand, time of day, and location, better-balancing supply and demand and offering the process more cost-effectively to consumers. These models can be more efficient and reach a larger user base when modeled with further research into pricing strategies and consumer behavior.

Going towards sustainability, there should be plans for future initiatives to find ways for SPARC to adopt renewable energy sources effortlessly. With the bi-directional EV charging system being such an important step in balancing energy demand, introducing more solar, wind or other renewable energy sources in the grid will be able to cut even more carbon footprint from these systems. Cities could collaborate with renewable energy providers to enhance a more sustainable and resilient energy infrastructure while participating in larger efforts around the globe toward greener energy.

Finally, the SPARC model is based on continuous data-driven optimization, which is necessary for long-term success. A key strength of the project is the use of real-time data in tuning parking and charging operations; however, the quality and reliability of this data must be continuously monitored and analyzed to improve the system's efficiency. Analysis of user feedback, patterns of energy consumption, and environmental impacts will continue to be required in refining the system. This iterative process will help keep SPARC solutions adaptive to the changing needs of urban environments.

The SPARC project concludes with an urban sustainability context for integrating advanced technologies to contribute to solving mobility and energy challenges. The recommendations suggested above to expand scope, improve stakeholder collaboration, refine digital interfaces, optimize pricing models, and increase renewable energy integration stand to scale the project's successes and contribute to the development of smarter, sustainable, global cities.

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References

1. Allam, Z., & Newman, P. (2021). Smart parking systems: Reviewing the literature, architecture, and ways forward. *Smart Cities, 4*(2), 623–642. https://doi.org/10.3390/smartcities4020032

2. EU Green Deal and Sustainable Urban Mobility Guidelines. (2024). European Commission Publications.
3. McKinsey & Company. (2022). Smart City Developments: Innovations in Urban Mobility.
4. Patel, B. (2024, November 12). How to create a parking finder app in 6 steps [Cost + tips]. Space-O Technologies. Retrieved December 12, 2024, from https://www.spaceotechnologies.com/blog/parking-spot-finder-app-development/
5. Rana, R., Saggu, T. S., Letha, S. S., & Bakhsh, F. I. (2024). V2G based bidirectional EV charger topologies and its control techniques: A review. *Discover Applied Sciences, 6*(588). https://doi.org/10.1007/s42452-024-06297-z
6. Rocco, G., Pipino, C. & Pagano, C. (2023). An Overview of Urban Mobility: Revolutionizing with Innovative Smart Parking Systems. Sustainability, 15(17), 13174. https://doi.org/10.3390/su151713174

LEVELS OF VEHICLE AUTONOMY IN PAKISTAN AND NEED TO DEVELOP THE INFRASTRUCTURE FOR AUTONOMOUS VEHICLES IN PAKISTAN

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Abstract

The primary aim of this research work is to bring autonomous vehicles onto Pakistani roads, the development of logistics corridors for autonomous vehicles, and the development of road infrastructure and digital infrastructure for commercial and non-commercial autonomous vehicles. In addition, it reduces road accidents and overcomes the issues of traffic congestion.
Both qualitative and quantitative research techniques were employed in this research work. Data was collected from both locally manufactured and imported miscellaneous types of commercial vehicles and non-commercial vehicles on Pakistani roads. The data gathered from the Pakistani driver's behavior including marijuana-impaired drivers is part of this research. Road infrastructure data is gathered.
There are six levels of vehicle autonomy as per the United States Society of Automotive Engineers. A very high percentage of Pakistan's miscellaneous types of commercial vehicles and non-commercial vehicles fall in the category of Level 0 or no driving automation. This is one of the major causes of road traffic accidents. Pakistani vehicle manufacturers/assemblers make the category of Level 0 vehicles. Level 1 is the lowest level of automation and a very low percentage of imported vehicles or non-commercial vehicles qualify under this category in Pakistan. As we enhance the levels of vehicle autonomy, the safety of the miscellaneous road users increases. Road surface markings are faded. Similarly, traffic control devices do not exist on many roads in Pakistan. The suspension or slowdown of 4G and 5G networks will also affect the introduction of autonomous vehicles in Pakistan.
The government of Pakistan needs to revisit its National Transport Policy 2018 and add about the manufacture / import of autonomous vehicles and the development of logistics corridors for autonomous vehicles. The government of Pakistan and the government of China need to transform the China-Pakistan Economic Corridor (CPEC) into logistics corridors for both commercial and non-commercial autonomous vehicles. A similar approach needed to be followed for other neighboring countries of Pakistan.

Key words: *autonomous vehicles, unmanned logistics corridors, levels of vehicle autonomy, traffic congestion, pakistan's national transport policy.*

Introduction

Pakistan has no rank in the 2020 Autonomous Vehicles Readiness Index (AVRI) (Assessing the Preparedness of 30 Countries and Jurisdictions in the Race for Autonomous Vehicles 2020

Autonomous Vehicles Readiness Index, n.d.). Singapore, Netherlands and Norway rank first, second and third in this race.

Studies have indicated that more than 90% of accidents are attributed to human error. Since autonomous vehicles eliminate the requirement for a driver, they have the potential to greatly enhance road safety. In addition to this, automated vehicles adhere to traffic regulations more effectively than humans and respond more swiftly. These vehicles can boost car-sharing initiatives, aiding in the reduction of congestion, making vehicle ownership in urban areas less appealing, and promoting new and innovative transportation solutions.

A system for classifying levels of driving automation comprises six distinct levels, which range from completely manual to entirely automated systems (2020).

The complete Society of Automotive Engineers (SAE) levels, which are now the standard in the United States and in areas that adhere to SAE regulations, are outlined as follows:

- Level 0 indicates that the human driver is responsible for all driving tasks.
- Level 1 allows an automated system in the vehicle to occasionally assist the human driver with certain aspects of driving.
- Level 2 means that an automated system can handle some segments of the driving task, while the human driver must still oversee the driving environment and manage the remaining tasks.
- Level 3 signifies that an automated system can perform specific driving tasks and monitor the environment at times, but the human driver must be prepared to regain control when the system requests it.
- At Level 4, an automated system is capable of handling the driving task and observing the driving environment, eliminating the need for the human to regain control; however, this automated system is limited to specific environments and conditions.
- At Level 5, the automated system can execute all driving tasks in every condition that a human driver is able to manage.
- It is thought that advancing vehicles to automation levels above SAE 3 is not practical unless the infrastructure is developed simultaneously. In this context, the roadway can direct and assist these vehicles by supplying real-time details about their upcoming environment.

Road Classifications for the Human-driven Vehicles

The conventional Functional Classification System (FCS) views the road primarily as a pathway for motorized vehicles. Transportation planners have utilized the FCS for many years to convey the character of service of a road. In its simplest form, the FCS is founded on two fundamental opposite dimensions: mobility and accessibility. While these two dimensions exist at opposing ends of the roadway function spectrum, most roads offer some blend of both, ensuring an appropriate level of road safety.

Table 1. SAE Automation levels for vehicles

SAE Level	Title	Description of the narrative		Implementation of guidance and speeding up/slow down	Observation of the driving surroundings	Performance backup for dynamic driving responsibilities	System functionality (driving settings)
Human drivers oversee the driving surroundings							
0	No Automation	The human driver is responsible for all elements of the dynamic driving task at all times, even when supported by warning or intervention systems.		Human driver	Human driver	Human driver	Not applicable
1	Driver Assistance	The driver assistance system executes "either steering or acceleration/ deceleration" based on the specific driving mode.	using data regarding the driving conditions and with the assumption that the human operator handles all other facets of the dynamic driving task.	Human driver and system			Some driving modes
2	Partial Automation	The execution by one or more driver assistance systems of both steering and acceleration/ deceleration is specific to the driving mode.		System			
The automated driving system observes the driving environment							
3	Conditional Automation	The performance of an automated driving system is tailored to the distinct driving modes regarding all elements of the dynamic driving task.	with the assumption that the human driver will react suitably to a prompt to take control	System	System	Human driver	Some driving modes
4	High Automation		even if a human driver fails to react suitably to a prompt to take control			System	Many driving modes
5	Full Automation		under all road and environmental conditions that can be handled by a human driver				All driving modes

Source: authors development

Roadway mobility: It offers limited options for entering and exiting, resulting in minimal travel friction from vehicle access and egress.

Roadway accessibility: It presents numerous chances for entry and exit, which can lead to greater friction from vehicle access and egress.

Along with mobility and accessibility, there are several other crucial aspects related to functional classification: (i) travel efficiency, meaning the fastest travel time, (ii) collector roads, (iii) points of access, (iv) speed limits, (v) spacing of routes, (vi) utilization – expressed as Annual Average Daily Traffic (AADT) volumes and vehicle miles traveled –, (vii) quantity of travel lanes, and (viii) significance on a regional and statewide level.

Regardless of the type or purpose of the trip, the following phases are typically recognized throughout an itinerary, which relate to the hierarchy of motor vehicle movements:

- Primary movement.
- Transition phase.
- Distribution stage.
- Collection phase.
- Terminal access point.

Each of the six stages of a standard trip is managed by a distinct facility specifically designed for its purpose. Due to the traffic volume hierarchy, freeway travel typically ranks highest, followed by distributor arterial travel, which is also higher in the hierarchy than travel on collectors and local access routes. This leads to a conventional system comprising arterial, collector, and local roads. While the interpretation of these road types might differ between countries or regions, a broadly accepted definition of the three terms is as follows:

- Arterials are primarily designed to facilitate vehicle movement, typically catering to longer journeys at a broader regional level.
- Collectors provide a mix of regional and local trips, acting as connectors between local access roads and arterial routes meant for mobility.
- Local streets are mainly focused on providing access, generally designed for lower speeds and often, though not exclusively, accommodating a narrower variety of vehicles.

Local roads primarily enhance accessibility, arterial roads improve mobility, and collector roads serve as a middle-ground solution between the two.

Nonetheless, none of the earlier classification frameworks take into account the emerging presence of Connected and Autonomous Vehicles (CAVs) on our roads. Connected and Automated Mobility (CAM) pertains to autonomous/connected vehicles or self-driving cars (European Comission, n.d.).

In light of this, two recent research projects have completed the integration of CAV-specific characteristics into road classification: The Connected Roadway Classification System (2019) and Road Infrastructure ready for mixed vehicle traffic flows (INFRAMIX) (2021).

The Connected Roadway Classification System (CRCS): It created a system for classifying roads utilizing three methods: (i) communication, (ii) seeing, and (iii) simplification. Communication pertains to the link between vehicles and infrastructure. This method is not reliant on any specific technology.

Two existing technologies are Dedicated Short Range Communications (DSRC) operating within the 5.9 GHz frequency and cellular communication, commonly referred to as C-V2X [Cellular V2X (Vehicle-to-Everything)]. An Infrastructure Owner/Operator (IOO) would implement and build

communication systems that facilitate Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) interactions. Improvements in infrastructure are linked to enhancing the functionality and precision of sensors within Connected and Autonomous Vehicles (CAVs), such as radar, cameras, and LIDAR. Examples include modifications to the shape, size, or materials used in signs, pavement markings, and traffic signal control systems. Lastly, simplifying refers to making adjustments to the geometric design of roadways to streamline the operation of CAVs, which involves altering access or usage, modifying roadway control, or changing alignment or cross sections to enhance safety and performance for CAVs.

Tables 2, 3, and 4 illustrate the proposed infrastructure methods, classification tiers, and standards associated with these tiers for the Connected Roadway Classification System (CRCS).

Limitations of automated driving

The influence of physical infrastructure on the automation potential of Connected and Autonomous Vehicles (CAVs) is given below:

Geometric design:

Several research studies have been conducted to examine how road geometric design affects the performance of connected and autonomous vehicles (Garcia, 2021). In particular, the most challenging scenarios occur at sharp horizontal curves and crest vertical curves due to the restricted visibility of the vision cameras mounted on the vehicles.

Cross-section:

The width of lanes, the type and width of shoulders, as well as the design of medians, significantly influence Connected and Automated Vehicles. While some studies have suggested that lane widths could be reduced because lane-related vehicle technologies—such as Lane Departure Warning (LDW), Lane Keeping Assist (LKA), and Lane Centering Assist (LCA)—will help keep vehicles centered in their lanes, existing vehicle systems often struggle with narrower lanes.

Road markings:

Detecting and tracking lanes, along with recognizing and identifying road markings on the road, are crucial for driver assistance systems, vehicle navigation, and route planning (2021). As a result, numerous studies have focused on creating algorithms that facilitate real-time detection of lane boundaries and support vehicle navigation. Nevertheless, there has been a lesser amount of research aimed at detecting horizontal pavement markings.

Most connected and autonomous vehicles (CAVs) demonstrate a high level of accuracy in detecting pavement markings when the following ideal conditions are met:

- A roadway that offers good visibility.
- During midday hours when sunlight rarely, casts shadows on the vehicle.
- Optimal weather conditions, with clear skies and dry pavement.
- Perfect pavement surface conditions, free from wear or outdated road markings that could confuse the machine vision system.
- Continuous and unobstructed road markings that comply with established standards.

Table 2. Connected Roadway Classification System. Guidelines for Communication.

Infrastructure approach	Infrastructure component	Connected Roadway Classification System Evaluation Categories			
		Requires Enhancement and Servicing	**Adheres to Present Best Practices**	**Aligns with Upcoming Market Trends (1-5 years)**	**Corresponds to Future Market Expectations (10 years)**
Communication		There is no capability for wireline or wireless communication.	Fiber-optic communication runs along the roadway, and cellular coverage is strong in the corridor.	DSRC or C-V2X nodes are connected to the fiber backbone.	Small cells are installed in the roadway right-of-way, providing robust 5G coverage and linking to the fiber backbone.
	Roadway				
	Traffic signals	The signal complies with the Manual on Uniform Traffic Control Devices (MUTCD), although its internal technology is outdated.	The signal adheres to the Manual on Uniform Traffic Control Devices (MUTCD) and utilizes modern technology. The signal functions as part of an interconnected system.	The signal is equipped with Vehicle-to-Infrastructure communication capabilities.	The signal broadcasts Signal Phase and Timing (SPaT) messages.
	Roadside equipment	There are few or no roadside devices that can communicate.	ITS equipment connects to a fiber backbone or has cellular capabilities for communication with the Traffic message channel (TMC).	The infrastructure component is also able to communicate using DSRC or C-V2X.	This infrastructure component shares information about conditions and performance while having local processing capabilities.
	Temporary traffic management devices	Traffic control devices are installed without the ability to communicate.	Temporary traffic control devices come with cellular communication capabilities.	The portable infrastructure component is fitted with technology that can communicate.	The portable infrastructure component relays information about conditions and performance.

Source: authors development

Table 3. Connected Roadway Classification System. Guidelines for seeing.

Infrastructure approach	Infrastructure component	Connected Roadway Classification System Evaluation Categories			
		Requires Enhancement and Servicing	**Adheres to Present Best Practices**	**Aligns with Upcoming Market Trends (1-5 years)**	**Corresponds to Future Market Expectations (10 years)**
Seeing	Roadway	Roadway assets are not documented in a digital format.	A digital inventory of roadway assets is available.	Significant corridors or regions have digital mapping.	Every roadway is digitally mapped.
	Signs	Signs might be absent, or if they are present, they may not be easily seen.	Signs achieve the intended level of visibility.	Signs offer the visibility required for recognition by connected autonomous vehicles (CAVs).	Signs incorporate technology that facilitates future machine visibility and analysis.
	Marking	Markings might be absent, or if they are there, they may not have the required visibility.	Markings achieve the necessary visibility.	Markings are evident, consistent, and offer the visibility required for recognition by CAVs.	Markings incorporate technology that allows for enhanced visibility and processing in the future.
	Traffic signals	Traffic signals require upgrades or maintenance.	The signal equipment complies with MUTCD standards.	The design and technology of the signal heads are consistent.	This area needs research.

Source: authors development

Table 4. Connected Roadway Classification System. Guidelines for simplification.

Infrastructure approach	Infrastructure component	Connected Roadway Classification System Evaluation Categories			
		Requires Enhancement and Servicing	Adheres to Present Best Practices	Aligns with Upcoming Market Trends (1-5 years)	Corresponds to Future Market Expectations (10 years)
Simplification	Roadway	The geometry of the infrastructure might not comply with AASHTO standards and/or the pavement is in inadequate condition.	The geometry of the infrastructure complies with AASHTO standards, and the pavement is free of defects.	The geometry of the infrastructure is intended to enhance the performance of CAVs.	The geometry of the infrastructure is uniquely designed to support the navigation and operation of CAVs.
	Temporary roadway geometry	There are few navigational aids provided for specified temporary geometry.	The navigational aids for temporary geometry adhere to MUTCD regulations.	The navigational aids for temporary geometry follow MUTCD standards, feature communication technology, and are made to be visible to CAVs.	Navigational aids for temporary geometric adjustments interact with vehicles and are intended to facilitate CAV navigation and functionality.
	Low-speed environments	No specific zoning or district designation for CAVs.	The infrastructure layout aligns with design standards, and the traffic control devices comply with MUTCD.	This area needs research.	This area needs research.
	Specialized infrastructure	No specific title for a facility dedicated to CAV.	Controlled lanes that have user access requirement.	This area needs research.	This area needs research.

Source: authors development

In other situations, the precision of road marking detection drops significantly, with the most challenging conditions being:

- Sunlight hitting directly from the front.
- Low-light conditions at night or roads with no lighting.
- Overcast weather or rain that obscures visibility.

- Roads that are wet or covered in snow.
- Pavement that is in poor condition or markings that are outdated.
- Degraded road markings or those that do not meet standards.
- Any combinations of the aforementioned factors.

Traffic signs:

Traffic signs established by the Vienna Convention and MUTCD are generally well-recognized by Traffic Sign Recognition (TSR) systems, as these systems are specifically trained to recognize these signs. Furthermore, these systems typically start by identifying the shape of the sign, then progress to recognizing the colors, and finally focus on the text or pictogram. This is why the Vienna Convention, being more symbol-centric, allows for enhanced TSR performance.

The regulations regarding the size, location, and installation of traffic signs aim to achieve two primary goals:

- The sign should be easily visible from a sufficient distance to the vehicles it affects.
- It must be clear which vehicles the traffic sign pertains to.
- To ensure that traffic signs are detected promptly, they should be placed in a manner that:
- They fall within the camera's field of view.
- There are no barriers obstructing the vehicle's line of sight to the sign.
- The angle between the road and the sign's alignment is not excessive.

The impact of sign location and alignment on the performance of Traffic Sign Recognition (TSR) systems is given below:

Table 5. The impact of sign location and alignment on the performance of Traffic Sign Recognition (TSR) systems

Element	Results
Side	• Signs are accurately positioned regardless of the side of the road they are on. • The background of the Region of Interest (ROI) where the image is situated does not appear to influence recognition.
Horizontal curve	A minor difference in sign recognition was observed when the signs are positioned at curves.
Transverse distance	• Recognition appears unaffected by moderate distances. • There is considerable variation in sign recognition within distances of up to 10 m: certain vehicles can recognize the signs while others cannot.
Orientation	The majority of systems can recognize the sign at angles up to 45° from the perpendicular to the road. Recognition becomes significantly more inconsistent among systems when the angle is between 45° and 55°.

Source: authors development

The upkeep of traffic signs is crucial for their clarity to Traffic Sign Recognition (TSR) systems. Maintenance involves various aspects, such as ensuring the sign is clean and free from vandalism, in good condition, and appropriate for its surroundings.

Road Junctions:

All research examining the advantages of connected and autonomous vehicles (CAVs) at signal-controlled intersections highlighted a significant decrease in both the frequency and severity of traffic conflicts and accidents. For market penetration rates (PMR) ranging from 50% to 100%, CAVs are projected to lessen the number of traffic conflicts by 20% to 65%, respectively. Regarding roundabouts, the anticipated reduction is between 29% and 64% with fully automated traffic (i.e., 100% PMR).

Connected vehicle technology has the potential to greatly enhance traffic flow at signalized intersections. Increases in the Performance Measure Rate (PMR) ranging from 0% to 60% can lead to a notable decrease in average delays. For example, in scenarios with low demand, delays can be reduced by as much as 60%. However, achieving these results requires a high level of automation; these vehicles must possess strong connectivity. Communication between vehicles (Vehicle-to-Vehicle or V2V) and between vehicles and infrastructure (Vehicle-to-Infrastructure or V2I) is crucial in this context.

Pavement condition

While some research has been conducted to assess how pavement quality impacts the performance of connected and autonomous vehicles (CAVs), it is evident that the condition of the road surface significantly affects automated driving. In this context, the updated road classifications that take into account the specific needs of these vehicles indicate that optimal pavement conditions are essential for reaching the highest automation levels.

Asphalt pavements tend to enhance the performance of connected and autonomous vehicles (CAVs) more effectively than concrete surfaces, as the former create a clearer distinction between road markings and the pavement itself. Furthermore, unexpected system disengagements can result from sudden road issues, such as potholes or rutting, as well as from outdated road markings. If pavement markings are inadequately removed and do not align with the wheel path, they can confuse machine vision systems, potentially leading to hazardous driving behavior. Similarly, sunlight reflecting off crack sealing can be misinterpreted as road markings by CAVs, which can result in undesirable vehicle performance.

The roughness of road pavement can cause inconsistencies when the camera records the line markings, potentially affecting the performance of machine vision. Nonetheless, due to constraints of time and budget, a thorough assessment was challenging, and instead, informal observations were noted regarding this issue (2020).

Moreover, if an automated vehicle is trailing or near another vehicle, a sudden and drastic change in the path of the vehicle ahead due to substantial road surface damage could create a challenging situation for the automated vehicle.

Another significant concern related to pavement is that the unique behavior of CAVs—traveling consistently in the center of the lane—will lead to a faster onset of rutting and other types of pavement

failures (such as potholes and cracking). Consequently, when designing CAV-specific lanes, it is essential to utilize materials for the surface layer that possess greater stiffness and durability. The frequency of maintenance for the underlying pavement layers may also need to be increased in the future. To mitigate this issue, recent research has introduced lateral control modes for automated vehicles.

Road environment

Along with the geometric layout, road surfaces, and traffic signs, other infrastructure elements like street lighting, bridges, and tunnels can also impact the effectiveness of CAVs. Research has shown that installing new lighting in areas previously unlit can decrease night-time accidents by 30-50%. In particular, accidents that occur under poor lighting conditions—even with some lighting present—result in significantly higher casualty rates compared to those that happen during the day, affecting both automated and traditional driving methods. Indeed, the likelihood of injuries tends to be greater with automated driving. Therefore, enhancing street lighting, whether by improving illumination or positioning lights more closely together, may be necessary to ensure that road markings, signals, and signs are clearly visible for optimal performance of CAVs.

Additionally, tunnels pose two significant challenges: (i) abrupt variations in lighting conditions and (ii) limited Global navigation satellite system (GNSS) signal availability. When an autonomous vehicle, which typically relies on vision cameras for environmental perception, enters or exits a tunnel, the abrupt changes in light may result in decreased accuracy in object identification. To improve the detection of road markings and recognition of traffic signs at these crucial points, various studies have suggested the advance detection of the tunnel to implement specific algorithms.

Automated vehicles today utilize a combination of information from the global positioning system (GPS), inertial navigation, and vision systems to determine their position. A significant challenge arises when trying to position the vehicle in areas where GPS signals are weak or unavailable, such as tunnels. To overcome this challenge, various inventive solutions have been proposed in some studies:

- Implementation of LED lighting (Jeong et al., 2019).
- Fusion of GPS, Lidar, and derived data.
- A landmark-based local positioning system (GIM et al., 2021).
- C-V2X positioning systems (Liu et al., 2021).

Environmental conditions

The primary environmental conditions influencing the performance of connected and autonomous vehicles (CAVs) are weather and lighting. Adverse weather situations, such as heavy rain and fog, hinder the ability to recognize road markings and traffic signs because these functions rely on visual cameras, which are greatly affected by visibility issues. During rainy conditions, the effectiveness of the detection systems is considerably reduced.

Additionally, the efficiency of detection systems can differ considerably when the pavement is moist. Although low ambient light can improve contrast and subsequently boost detection, overly bright ambient light may lead to a "light bloom" effect, greatly impairing the detection system's effectiveness. The changes in lighting conditions throughout the day make lane detection less effective compared to night-time. Nonetheless, street lighting at night can hinder the accuracy of vision cameras in terms of color differentiation. As previously mentioned, the vision systems in CAVs may misinterpret yellow and red traffic signals, resulting in confusion regarding traffic lights. According to Shladover and Bishop, enhancing the visibility of road markings, signals, and signs is crucial for the effective operation of CAVs and may necessitate improved street lighting, whether through enhanced illumination or lights placed at closer intervals.

Automated vehicles are vulnerable to glare from direct sunlight. Cameras that capture images in direct sunlight with standard dynamic range need to adjust for the brightness of the sun, often resulting in an over-exposed background and an under-exposed foreground in the images. This issue contributed to the first fatality involving an automated car in 2016 when a Tesla Model S crashed into a white tractor trailer. Since that incident, research has been conducted to improve object detection in bright sunlight.

Vulnerable road users

Certain studies have concentrated on exploring the capability of CAVs to lower pedestrian death rates. In this context, the algorithms that make decisions regarding pedestrian crossing detection are regularly refined to capture a wide range of pedestrian behaviors. Nevertheless, the paths taken by humans can be unpredictable at times, increasing the risk of accidents. Merging various sensor technologies shows the greatest potential for eliminating fatalities, though it could be prohibitively expensive. Current research in real-time object recognition has produced encouraging outcomes for detecting pedestrians at crosswalks, but additional studies are required to enhance the sensing and detection capabilities at pedestrian crossing sites.

The greatest challenge for connected and autonomous vehicles (CAVs) comes from the lightest, quietest, and most manoeuvrable vehicles on the roads, namely bicycles. Existing technologies struggle to anticipate the actions of cyclists. Furthermore, the detection of this type of vehicle can create confusion for the system, as it identifies the bicycle and the rider as two distinct objects.

Numerous automotive manufacturers, backed by scientific studies, are working on safety and communication systems designed to prevent collisions with non-motorized road users, such as pedestrians and cyclists. However, the majority of these innovations are primarily focused on the vehicle's perspective, overlooking the situation from the vantage point of pedestrians and cyclists (Vissers et al., 2016). Significant challenges remain to be addressed (for instance, ensuring reliable performance in poor weather conditions), and developing technology that can consistently anticipate the intentions and behaviors of pedestrians and cyclists proves to be even more complex.

Present engagement habits and approaches cannot be directly applied to scenarios involving automated vehicles or vehicles that feature varying degrees of automation. Pedestrians and cyclists may act based on mistaken or unfounded assumptions regarding the actions of these vehicles. At the same time, the vehicles may struggle to accurately understand the actions of pedestrians and cyclists, as their

responses when interacting with an automated vehicle could vary from those when engaging with a human-operated vehicle.

Another category of vulnerable users consists of powered two-wheelers, which are often not recognized by CAV sensors and algorithms. Research examining the detection capabilities of Adaptive Cruise Control across various models from different car manufacturers – including Jeep, Hyundai, Skoda, Volvo, VW, and Tesla – found that detecting motorcycles is only feasible when the rider is positioned more than 1.20 m from the vehicle's or lane's centerline.

Temporary emergency signage

Temporary structures may be erected on roadways due to local needs or accidents, which can include temporary emergency signs that could block or affect regular driving. In Pakistan, police normally use the big shipping containers to block the roadways in political or other kind of demonstrations. The algorithms used by CAVs are currently insufficient to recognize and understand signage that often does not adhere to any established standards or guidelines. For example, while present-day CAVs can detect pedestrians, they struggle to interpret signals given by police officers. In summary, temporary emergency signage lacks consistent and clear patterns, making its interpretation more challenging than that of road work signs.

A prompt geo-referencing of this kind of signage on HD maps would facilitate its acknowledgment and enable CAVs to process the information ahead of time.

Speed

Advanced Driver Assistance Systems (ADAS) typically function within a certain speed range. For instance, Adaptive Cruise Control (ACC) generally operates from a speed of 30 km/h, while Lane Keeping and Centering Assist (LKA and LCA) systems become active only when the vehicle reaches speeds above 60 km/h. As a result, many of the currently available automated vehicles are unable to operate autonomously in urban areas, where the maximum speed limit is 50 km/h, due to manufacturer limitations.

Various forms of Intelligent Speed Assistance (ISA) systems have been created, offering distinct levels of driver support and feedback (Ryan, 2018):

- Advisory/Warning (open).
- Supportive/Intervening (half-open).
- Mandatory limiting/Automatic control (closed).

An open level of support simply alerts the driver when they surpass the posted speed limit at a certain location, while the half-open level can manage the throttle, although the driver can still go over the speed limit. In contrast, a closed system prevents drivers from exceeding the speed limit by automatically restricting the vehicle's maximum speed. In this regard, Intelligent Speed Assistance (ISA) systems can utilize speed limits in various manners:

- Fixed speed limits, such as those indicated by signs.
- Adjustable speed limits that apply in certain areas like sharp turns or construction zones.
- Real-time speed limits that depend on current road and traffic situations.

However, for a high degree of automation, the Intelligent Speed Assistance (ISA) will have to rely not just on speed limits, but also on the operational speed profiles selected by the automated system or established by the Traffic Management Center. This advanced level of ISA could be referred to as dynamic-closed.

Additionally, speed plays a crucial role in recognizing road markings, as the system must analyze the collected data more rapidly when vehicle speeds increase. In connection with this issue, It is introduced the concept of Automated Speed, which refers to the highest velocity an automated vehicle can maintain at a given road geometric feature. Consequently, challenging road elements, such as sharp turns and steep inclines, are linked to reduced automated speeds. Therefore, high-capacity rural roads (like freeways and expressways), which typically offer a smoother geometric design, enable connected and autonomous vehicles (CAVs) to function autonomously. Conversely, two-lane rural roads, which often include numerous challenging road features, may lead to frequent system disengagements.

In terms of road marking configuration, the ability to recognize dashed lines is influenced by the speed of the vehicle. A study by Austroads found that road markings with a width of 150 mm, featuring 9 m of solid line and 3 m of spacing, were identified with greater accuracy at speeds of 60-70 km/h compared to 80 km/h. Conversely, road markings that comprised a width of 150 mm, with 3 m of solid line and 9 m of spacing, achieved detection accuracy rates of 100% at 80 km/h and 90% at 60-70 km/h. On roads with either fair or poor pavement quality, speed is a crucial factor as well. The presence of pavement issues can result in more severe vehicle manoeuvres at increased speeds, which in turn leads to more regular system disengagements.

Digital Infrastructure:

The precise positioning of automated vehicles is crucial for ensuring road safety. These vehicles employ a variety of independent positioning techniques, including satellite positioning, inertial positioning, mobile network positioning, as well as car sensors and high-definition maps. Nevertheless, achieving the required accuracy in satellite positioning relies on the support of RTK (Real-Time Kinematics) land stations. Consequently, the digital infrastructure essential for automated vehicles is the network RTK positioning approach, which facilitates real-time, high-precision Global Navigation Satellite System (GNSS) based positioning using Global Navigation Satellite System (GNSS) carrier-phase data.

In this situation, tunnels pose a difficult challenge as they typically offer limited Global Navigation Satellite System (GNSS) signal coverage. To overcome this limitation, several studies have proposed innovative solutions:

(i) implementation of LED lighting,

(ii) integration of GPS, Lidar, and derived data,

(iii) a landmark-based local positioning system, and

(iv) Cellular V2X (Vehicle-to-Everything),C-V2X positioning systems. Nonetheless, additional research in this area is essential to establish standardized solutions that are compatible with the capabilities of automated vehicles.

Additionally, High-Definition Maps (HD Maps) assist with the localization, detection, prediction, and planning processes for Automated Vehicles when used alongside Global Navigation Satellite System (GNSS) and Inertial Measurement Unit (IMU) sensors. Numerous map providers and original

equipment manufacturers (OEMs) are working on HD Maps that offer precision at the centimeter level. However, there currently exists no widely accepted open standard for the production of HD Maps. The development of HD Maps consists of five primary stages:
(i) conducting a Mobile Mapping System (MMS) survey using LiDAR,
(ii) creating 3D models,
(iii) editing feature attributes and establishing road network topology,
(iv) converting formats, and
(v) conducting quality assurance.
The HD maps are progressing into a Dynamic Map that comprises four layers of geographical information:
(i) dynamic data,
(ii) semi-dynamic data,
(iii) semi-static data, and
(iv) static data. The static data is what is referred to as the HD map.
Dynamic data, semi-dynamic data, and semi-static data are those that vary based on factors such as traffic conditions, weather, and scheduled work zones, whereas road surface details, lane information, and 3D coordinates of road structures represent information that remains stable over time.
Automated vehicles must keep a close watch on all activities occurring along their path, extending even past the limits of their sensory equipment. Connected and automated vehicles, equipped with advanced sensing technologies, contribute to the solution by supplying accurate information regarding conditions, traffic situations, and incidents they experience while traveling. However, there is a need for enhancements in the quality of traffic information, which will steadily improve as the presence of connected and highly automated vehicles increases.
They essentially require two varieties of information systems. The first is real-time data regarding incidents, roadwork, events, congestion, and other obstacles on the upcoming route, providing advance notice of issues beyond the vehicle's sensor range. The second encompasses the laws and regulations related to any upcoming restrictions for automated driving, which includes real-time traffic management details and dynamic geofencing information to prevent routing through restricted areas.
There are two methods for conveying digital traffic information and rules to road users: one for CAVs through service providers utilizing connectivity, and the other for drivers through Variable Message Signs (VMS), as is currently done. Automated driving systems could also gain from a standardized and uniform application of pictograms by various stakeholders, although the complete message content would be preferable.
Automated vehicles require up-to-date information on the traffic conditions within the road network, including both the present situation and forecasts for future traffic behavior. The idea of a virtual transport system, or a digital representation of the transport network as part of the digital infrastructure, could be extremely beneficial for accessing this latter information. Implementing digital twins in traffic management allows for the simulation of the effects of various traffic control strategies to pinpoint the most effective approach in real time, as well as in fleet management to model the consequences of different routing options for specific vehicles or transports to select the most optimal routes, thereby enhancing safety and performance.

Incorporation of Connected and Autonomous Vehicles within the Road Infrastructure

An effective Smart Roads Classification system must take into account the constraints associated with the interaction between Connected and Autonomous Vehicles (CAVs) and the road infrastructure.
There are five levels of smart roads classification is suggested (García et al., 2021.

(i) Humanway (HU) road segments: These road segments are not conducive to automation. The infrastructure is not adequately prepared to accommodate Connected and Autonomous
Vehicles (CAVs), primarily due to a significant frequency of disengagements and/or insufficient capacity to disseminate digital data that would inform vehicles about their Operational Design Domains (ODDs).

(ii) Assistedway (AS) road segments: These road segments offer limited support for automation, exhibiting significantly fewer disengagements compared to Humanway (HU) road segments. While the road segment is suitable for autonomous operation, this capability may be interrupted by various factors, albeit less frequently than in Humanway (HU) segments. Consequently, operators of vehicles with automation levels 1 to 4 must remain vigilant regarding potential disengagements or takeover requests.

(iii) Automatedway (AT) road segments: These road segments exhibit comparable physical attributes to those of Assistedway (AS) road segments, while also offering connectivity features that may assist connected vehicles in preventing and avoiding disengagements. The road segment demonstrates adequate connectivity and physical infrastructure capabilities, resulting in a significantly reduced likelihood of disengagements or takeover requests in comparison to Assistedway (AS) and Humanway (HU). Vehicles are able to align their operational design domain (ODD) limitations with the digital information provided by the road segments, thereby allowing for the majority of takeover requests (levels 3-4) to be anticipated.

(iv)Full Automatedway (FA) road segments: These road segments offer comprehensive support for SAE level 4 vehicles, along with robust connectivity features. The roadway includes a continuous operational road section (ORS), which guarantees operational design domain (ODD) compatibility for the majority of level 3 and 4 vehicles. Digital information is disseminated, enabling these vehicles to effectively manage any takeover requests. As a result, a seamless driving experience without disengagements can be achieved. Level 2 vehicles, on the other hand, would encounter a minimal number of disengagements.

(v) Autonomousway (AU) road segments: These road segments offer comprehensive support for SAE level 4 vehicles and possess outstanding connectivity features. Access is restricted solely to SAE level 4 and 5 vehicles. Similar to Full Automatedway (FA), the connectivity infrastructure facilitates cooperative driving, enabling the infrastructure to both receive and transmit customized instructions to all vehicles, thereby optimizing traffic performance. This type of road segment is exclusively reserved for level 4-5 connected and autonomous vehicles (CAVs). Certain lanes may be designated for this highest level of automation.

Safety Aspects of Connected and Autonomous Vehicles

The effects of automated driving on safety can be evaluated across various levels (Sohrabi et al., 2021): (i) vehicle, (ii) transportation system, and (iii) society . At the vehicle level, Connected and Autonomous Vehicles (CAVs) can be assessed based on their influence on key driver-related factors that contribute to accidents, such as distractions, lack of attention, marijuana smoking of Pakistani drivers or performance errors. At the transportation system level, it is anticipated that CAVs will lead to a decrease in traffic conflicts and accidents. At the societal level, traffic accidents represent a significant public health issue, and the health implications of CAVs can be analyzed by comparing the frequency of accidents under different Penetration Market Rates (PMR), including scenarios involving solely human-operated vehicles.

The anticipated elimination of traffic accidents resulting from driver error following the deployment of connected and autonomous vehicles (CAVs) may be undermined by various safety concerns. These include:

(i) failures in system operation,
(ii) vulnerabilities to cybersecurity threats,
(iii) the potential for riskier behaviors among users,
(iv) an increase in overall traffic flow,
(v) challenges associated with mixed traffic conditions, and
(vi) issues of inequity and ethics, particularly if CAVs are predominantly accessible only to affluent consumers. It is evident that the safety implications are closely tied to the levels of automation present in the CAVs available in the marketplace.

Mobile networks and 5G

In recent years, there has been considerable discussion regarding the various communication systems that will support connected autonomous vehicles (AVs). Although these systems can coexist, there is an increasing agreement that a significant number of AVs will rely on the functionalities provided by mobile networks. These networks are composed of stationary base stations that facilitate two-way communication between the network and nearby users, along with a network of fibre-optic cables or radio links that interconnect individual base stations to the broader network.

The fifth and most recent generation of mobile connectivity, known as 5G (5G Automotive Association, n.d.), commenced its introduction in the latter part of the 2010s. Telecommunications providers have initiated the deployment of 5G networks primarily in urban centers and larger suburban regions where demand is most pronounced. With the advent of autonomous vehicles, 5G is poised to become the most advanced communication standard in common usage. China-Pakistan Economic Corridor (CPEC) needs to transform into 5G Corridor infrastructure (5G Corridor Deployment, 2024). 5G serves as a comprehensive term encompassing various communication systems that are implemented collectively to ensure data connectivity. Systems that operate on lower frequencies with limited bandwidths can deliver a reasonable capacity over extensive areas through a single cell. Conversely, systems that utilize higher frequencies can offer over a hundred times the capacity, enabling them to meet significantly higher data demands, albeit over a more restricted area. To achieve

adequate overall capacity for 5G, a combination of these systems is necessary to address the anticipated usage levels.

Automated transportation and a range of innovative mobility services will generate new demands for mobile communication networks along major roadways globally. The data transmission requirements are expected to differ across various roads and segments of the road network. For instance, the use cases for automation will significantly differ between well-structured highways and congested urban areas.

A widely held perspective is that the existing 4G/LTE mobile networks adequately meet the majority of today's digitalization needs, even before the advent of autonomous vehicles (AVs). As 4G technology continues to evolve and enhance its performance, the migration of traffic from 4G to 5G networks further contributes to the optimization of the 4G network.

The anticipated increase in future traffic underscores the significance of 5G technology, as its enhanced transfer speeds, increased capacity, and reduced latency will become progressively vital.

In areas characterized by significant traffic volumes, the implementation of high-capacity 5G networks will be essential to accommodate the growing demand for capacity. Use cases involving automation, where latency is critical for safety, particularly necessitate the capabilities offered by 5G or Dedicated Short-Range Communications (DSRC). Additionally, data-intensive applications require 5G networks, especially when utilized by numerous users within a confined area and limited cell coverage. It is imperative that the quality of service for transport automation remains uncompromised despite the sharing of network capacity with a large number of other users. 5G technology incorporates isolation mechanisms designed to allocate a specific portion of the network for designated users.

As the significance of mobile networks becomes increasingly evident, policymakers and infrastructure operators must soon regard mobile connectivity as an essential component of road safety. On heavily trafficked highways, this will likely necessitate the implementation of consistent 5G connectivity. Traditionally, many countries have not devised strategies to guarantee uniform mobile network coverage across transportation networks, and establishing a dependable connection along the busiest highways will demand coordinated efforts. Whether this initiative is driven by government intervention or private sector investment will likely depend on local conditions; however, the ultimate objective must be to ensure adequate coverage for user safety. Additionally, a myriad of interconnected issues, such as interoperability, cyber security, resilience, reliability, privacy, and data governance and ownership, must also be addressed.

Conclusions

(i) Pakistan based company “Pakneftegaz” is looking international partners / researchers to jointly conduct research and convert the present infrastructure into Connected and Autonomous Vehicles (CAVs) related infrastructure in Pakistan.

(ii) Connected and Autonomous Vehicles (CAVs) is the solution of traffic congestion problem in many cities of Pakistan. In this context, company “Pakneftegaz” is ready to provide the solution to the federal government and provincial governments.

(iii) Government of Pakistan need to develop the 5G transport corridors with its regional countries.

(iv) Pakistan based company “Pakneftegaz” is proposing to Estonian Entrepreneurship University of Applied Sciences and Estonian government to jointly work in the area of Connected and Autonomous Vehicles (CAVs).

References

1. Assessing the preparedness of 30 countries and jurisdictions in the race for autonomous vehicles 2020 Autonomous Vehi cl es Readi ness I ndex. (n.d.). https://assets.kpmg.com/content/dam/kpmg/xx/pdf/2020/07/2020-autonomous-vehicles-readiness-index.pdf
2. (2020). Classification of Readiness of European Highways for Adopting Connected, Automated and Electric Vehicles. European Asphalt Pavement Association (EAPA). https://www.asphalt.de/fileadmin/user_upload/downloads/EAPA-Brosch%C3%BCren/1-Classification-of-Readiness-of-European-Highways-for-Adopting-Connected-Automated-and-Electric-Vehicles.pdf
3. (2019). CONNECTED ROADWAY CLASSIFICATION SYSTEM DEVELOPMENT. National Cooperative Highway Research Program Transportation Research Board of The National Academies of Sciences, Engineering, and Medicine. https://onlinepubs.trb.org/Onlinepubs/nchrp/docs/20-24112CRCSDevelopmentPreliminaryFinalContractorsReport.pdf
4. (n.d.). Connected and automated mobility. https://digital-strategy.ec.europa.eu/en/policies/connected-and-automated-mobility
5. (2021). Inframix EU Project. https://www.inframix.eu/
6. Garcia, A. (2021). Determination of minimum horizontal curve radius for safe stopping sight distance of vehicles overpassing truck platoons. Computer-Aided Civil and Infrastructure Engineering. https://onlinelibrary.wiley.com/doi/full/10.1111/mice.12758
7. (2021). Impacts of Automated Vehicles on Highway Infrastructure [Review of Impacts of Automated Vehicles on Highway Infrastructure]. Research, Development, and Technology Turner-Fairbank Highway Research Center, United States department of transportation, Federal Highway Administration. https://www.fhwa.dot.gov/publications/research/operations/21015/21015.pdf
8. (2020, September 25). Implications of Pavement Markings for Machine Vision. Austroads. https://austroads.gov.au/publications/connected-and-automated-vehicles/ap-r633-20
9. Jeong, J.-H., Byun, G.-S., & Park, K. (2019). Tunnel lane-positioning system for autonomous driving cars using LED chromaticity and fuzzy logic system. ETRI JOURNAL. https://onlinelibrary.wiley.com/doi/full/10.4218/etrij.2018-0192
10. GIM, J., AHN, C., & PENG, H. (2021). Landmark Attribute Analysis for a High-Precision Landmark-Based Local Positioning System. IEEE Acess. https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9330508
11. Liu, Q., Xia, J., Wang, T., Song, M., Xu, X., Zhang, J., Fan, Y., & Liu , L. (2021). A Highly Accurate Positioning Solution for C-V2X Systems. https://www.mdpi.com/1424-8220/21/4/1175

12. Vissers, L., der Kint, S. van, van Schagen, I., & Hagenzieker, M. (2016). Safe interaction between cyclists, pedestrians and automated vehicles. SWOV Institute for Road Safety Research, The Netherlands. https://swov.nl/system/files/publication-downloads/r-2016-16.pdf
13. Ryan, M. (2018). Intelligent Speed Assistance: A review of the literature. Road Safety Authority (RSA). https://www.rsa.ie/docs/default-source/road-safety/r4.1-research-reports/intelligent-speed-assistance/intelligent-speed-assistance-a-review-of-the-literature-2018.pdf
14. García, A., Camacho-Torregrosa, F. J., Castelló, D. L., & Monserrat, J. F. (2021). Smart Roads Classification. https://riunet.upv.es/bitstream/handle/10251/189900/GarciaCamacho-TorregrosaLlopis-Castello%20-%20Smart%20Roads%20Classification.pdf?sequence=1
15. Sohrabi, S., Khodadadi, A., Maryam Mousavi , S., & Dadashova, B. (2021). Quantifying the automated vehicle safety performance: A scoping review of the literature, evaluation of methods, and directions for future research. https://sci-hub.se/downloads/2021-05-18/33/sohrabi2021.pdf
16. 5G Corridor deployment. (2024, October 22). Shaping Europe's Digital Future. https://digital-strategy.ec.europa.eu/en/policies/cross-border-corridors
17. 5G Automotive Association. (n.d.). 5gaa.org. https://5gaa.org/

MODELLING OF PROCESSES OF HYBRID TECHNOLOGY OF MANAGEMENT OF INFRASTRUCTURE PROJECTS OF POST-WAR RECONSTRUCTION

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Abstract

A structural model for managing post-war transport and security infrastructure restoration projects is proposed, which includes four key elements: project environment, project, project product, and project management. This framework helps to identify the specific features of managing such projects and establishes relationships between their indicators. It is found that restoration projects have a common project environment and resources, and their products interact, increasing value for stakeholders.

The article proves that an important feature of the management of infrastructure restoration projects in the post-war period is the need to choose the optimal management technology. The study of hybrid management methodologies of infrastructure programs is determined by the practice of implementing software components that differ in their essence. The model of hybrid management of infrastructure reconstruction projects in the post-war period is presented, which includes three main components: resource availability, determination of requirements for project results, and project complexity. For each of these components, appropriate evaluation criteria are defined, which form the basis of the management characteristics of these projects. We have characterised in detail the elements of infrastructure restoration projects and identified the relationships between their indicators. It was established that post-war infrastructure reconstruction projects function in a common project environment and share resources.

Introducing hybrid management models will facilitate effective cooperation between teams involved in recovery in different sectors of the economy. This will be especially useful when it is necessary to organise interaction not only within the project team but also with the team responsible for ensuring sustainable development.

Keywords: *management, infrastructure projects, restoration, modelling, hybrid technologies.*

Introduction

In the conditions of dynamic changes in the project environment, military threats, instability and turbulence, the threat to the safety of life of the population and territories has increased rapidly. Unjustified Russian war of aggression as of September 1, 2024. caused damage to Ukraine's infrastructure in the amount of more than 155 billion US dollars. The modern world is becoming increasingly dependent on the infrastructure that ensures the functioning of the economy and the life of the population, especially in martial law conditions. Objects of critical infrastructure, such as energy networks, hydro, thermal, nuclear power plants, transport highways, communication and communication systems, and others, play an important role in ensuring this functioning. At the same time, these objects can and are exposed to risks and threats, which leads to serious consequences for the safety of life. Due to hostilities, the amount of direct losses from the destroyed infrastructure of the energy industry continues to grow — up to $9 billion.

An important feature of the management of infrastructure restoration projects in the post-war period is the need to choose the optimal management technology. This state of affairs created the need to develop new approaches to the use of hybrid technology for managing infrastructure projects in the conditions of post-war recovery. The study of hybrid methodologies of managing infrastructure programs is determined by the practice of implementing software components that differ in their nature.

Analysis of recent research and publications

Numerous scientists are actively studying the practical aspects of post-war reconstruction to promote the development of countries during this period. An important contribution to solving the problem of post-war recovery was made by S.V. Ivanov, who emphasises that for the successful economic reconstruction of the country, it is necessary to develop and implement a modern concept based on innovative development, taking into account the current geopolitical conditions (Ivanov, 2019).

Yu. A. Priymakov, in his research, made a similar conclusion, using economic-mathematical modeling to manage reconstruction projects in the post-conflict period (Priymakova, 2020). In agreement with these ideas, we believe that it is worth investigating the use of hybrid project management technologies more deeply to accelerate the recovery of the economy in the post-war period.

Most of the studies related to the transformation of project management in various areas of the economy focus on the combination of management technologies, not taking into account their synergistic potential. Therefore, it is important to continue the adaptation of project management to the new conditions of economic development, because the correct choice of a project management methodology or model is critical not only for the success of an individual project, but also for the achievement of strategic business goals.

In today's dynamic project management environment, hybrid approaches are gaining more and more popularity. This is due to their ability to combine adaptability and predictability, integrating project management methods that are based on planning and flexibility (Azenha and etc., 2021). International studies in various fields indicate a high level of use of hybrid methodologies: for example, studies have shown that 62% and 52% of projects, respectively, use hybrid approaches (Gemino and etc., 2021) .

The traditional model of project management (cascade methodology, or Waterfall) involves the sequential implementation of project stages, which makes it clearly planned and logical. However, this model does not provide a quick response to changes in the external environment. An Agile approach (flexible methodology) was developed to improve interaction with stakeholders and prompt response to changes. Studies (Krupa & Hajek, 2022) show that the use of Agile allows to align the effectiveness and level of satisfaction of stakeholders with the goals of the organization, and the quality of the goals or vision of the project is a key factor. However, the disadvantage of this approach is the high risk for the customer regarding compliance with deadlines, budget and project results. A variety of concepts, methodologies and tools are used to put these core models into practice, including Lean, Scrum, Kanban, PRINCE and PRINCE2.

The disadvantages of the models listed above led to the emergence of hybrid methodology (Hybrid Project Management / HPM), the essence of which is a combination of models or individual methods or methods in various combinations.

WITH. Bushuev and B. Kozyr (Bushuev & Kozyr, 2020) emphasise that the different life cycles of the components of large (infrastructural) projects require developing an approach that will ensure the integration and harmonisation of project management methodologies. They offer a system of hybrid multi-level management of infrastructure projects and programs. To effectively implement this hybrid model, combining the mechanisms of harmonisation, integration, convergence, actualisation and dual management is necessary, which, in turn, have a complex structure and functions.

Research by A. Ivko (Zvarych I.T. & Zvarych O.I., 2017) considers eight variations of combinations of hybrid models, while M. Krupa and J. Hayek (Serrador & Pinto, 2015) describe 22 HPM models and nine meta models.

To date, a rather limited number of publications focus on various aspects of an important development area, such as the effective use of hybrid infrastructure project management technologies in the context of post-war reconstruction.

Presentation of the main research material

The infrastructure project for the restoration of transport infrastructure after the end of hostilities includes a set of unique and temporary measures implemented in a special project environment. The purpose of such actions is to restore damaged infrastructure facilities to their pre-war condition or to modernize them to improve their functionality. The end result is the creation of a reliable transport network that ensures uninterrupted transport and contributes to the restoration of economic and social activity. The main tasks of such projects include the repair of roads damaged as a result of hostilities, as well as their reconstruction in order to increase their capacity and level of security.

The project for the restoration of post-war security infrastructure provides for a set of actions that have unique features and a limited time frame. These actions are aimed at restoring security facilities or modernizing them in order to ensure an adequate level of protection of the population from possible threats. The result is a modern security system that is able to effectively respond to emergencies. The main tasks include the repair of damaged civil protection facilities and the modernization of fire and rescue services to increase their efficiency and effectiveness.

Transport and security infrastructure restoration projects have many common characteristics and are interconnected, as both contribute to the creation of a sustainable infrastructure base. An efficient transport network is critical to supporting security facilities, ensuring the delivery of necessary resources and personnel, as well as the possibility of rapid evacuation in the event of a threat. At the same time, a reliable security infrastructure is an important condition for the stable operation of the transport system, reducing risks to people's lives and protecting cargo. Thus, the implementation of these projects requires a systemic approach and coordination from a single project office that has full access to up-to-date information on all areas of activity.

We propose a structural model for managing transport and security infrastructure restoration projects in the post-war period are shown inTable 1.

This model emphasizes a systemic approach to project management, integrating all components into a single project environment to ensure comprehensive infrastructure restoration in the post-war period.

The main difference between these projects is the common project environment, which includes various factors. This environment is determined by such groups of factors as natural and climatic conditions, geographical location, demographic and socio-economic indicators, the level of infrastructure development and the state of security. The main characteristics of the elements of projects for the restoration of transport and security infrastructure:

1. Transport Infrastructure Restoration Project:
   - Project Environment: Takes into account natural and climatic conditions, geographical location, demographic and socio-economic status, level of infrastructure development, and security status.
   - Project: Covers a set of measures aimed at restoring existing transport infrastructure facilities to their pre-war condition or their modernization.
   - Project Product: This is a restored or modernized transport infrastructure that ensures the proper functioning of transport.
   - Project Management: Includes management processes, methods and models used to effectively manage the restoration of transport infrastructure.
2. Security Infrastructure Restoration Project:
   - Project Environment: Similarly includes natural and climatic conditions, geographical location, demographic and socio-economic status, level of infrastructure development, and security status.
   - Project: Covers a set of actions aimed at restoring existing security infrastructure facilities to their pre-war condition or their modernization.
   - - Project Product: This is a modernized or restored security infrastructure that provides protection to the population from potential threats.
   - Project Management: Covers management processes, methods and models for the effective implementation of security infrastructure restoration tasks.

Table 1. Structural model for managing projects for the restoration of transport and security infrastructure in the post-war period

Main components of the model
1. Project environment: - Includes natural and climatic conditions, geographical location, demographic indicators, socio-economic status, as well as existing transport and security infrastructure. - These are the basic conditions on which the project management process is based.
2. Rehabilitation projects: - Transport infrastructure rehabilitation project: involves the rehabilitation or modernization of existing transport facilities (roads, bridges). - Security infrastructure rehabilitation project: includes the rehabilitation or modernization of facilities that ensure the safety of the population (civil protection systems, shelters).
3. Technical and technological equipment: - Both projects include appropriate technical support and equipment for the successful implementation of restoration works.
4. Contractors: - Groups of specialists and contractors who perform specific tasks within both projects.
5. Database and knowledge base: - Contains all the necessary information for planning and monitoring projects, including data on resources, technical condition of facilities, results of assessments and research.
6. Project Management Office: - A central structure that coordinates the implementation of both projects, manages resources and monitors the progress of task implementation. Interrelationship of components: - The existing infrastructure affects the project environment, which forms the initial data for the implementation of both projects. - The project management office integrates information and coordinates actions, ensuring the effectiveness of project implementation. - The projects have common resources and a common database, which allows synchronizing the processes of restoring transport and security infrastructure, reducing costs and increasing efficiency.

Source: authors development

This approach helps to detail the components of projects, identify their products and management processes necessary to implement infrastructure restoration in the post-conflict period. Key provisions of post-conflict transport and security infrastructure restoration projects (Smith, J., Taylor, A. (2023). Jones, L. (2022). Williams, K., Peterson, D. (2020).):

1. The project environment includes natural and climatic conditions, geographical location, demographic and socio-economic indicators, level of infrastructure development and safety.
2. Characteristics of transport infrastructure include:
   - Quality of roads (paved and unpaved).
   - Accessibility of vehicles and services for residents.

- Availability of engineering structures (bridges, traffic interchanges).
- Level of road safety (traffic intensity, road condition, presence of pedestrian crossings).

3. Characteristics of safety infrastructure include:
   - Physical facilities (fire protection facilities, shelters, warning systems).
   - Organizational components (safety management systems, personnel training).
   - Information component (communication and safety information systems).

4. The link between transport and security infrastructure: an efficient transport infrastructure is the basis for the functioning of security infrastructure and ensures the rapid delivery of resources and the evacuation of the population in case of emergencies.

5. The assessment of the effectiveness of infrastructure recovery projects takes into account the interdependence of transport and security infrastructure, which determines the overall safety and comfort of life.

This approach provides a general understanding of the importance of an integrated approach in managing infrastructure restoration projects and the need to use systems analysis methods to assess the current state and plan restoration activities (Brown, S., Davis, M. (2021).

1. For the successful implementation of projects to restore transport and security infrastructure after the end of hostilities, it is necessary to solve a number of specific scientific and practical tasks related to individual aspects of these projects. In view of this, specific tasks were identified and management tools were proposed that need to be developed for project managers in order to effectively solve the tasks set (table 2) (Evans, T., Garcia, P. (2020), Chen, X., Lee, H. (2021), Roberts, S., White, R. (2022), Nelson, J. (2021), Popova O. et al. (2023).

This format will help to more clearly understand the specifics of the tasks and methods for solving them within the framework of the implementation of transport and security infrastructure restoration projects.

Based on the data in Table 2, it can be concluded that the analysis of the state of the project environment involves the use of modern analysis methods and information technologies, which allow obtaining more accurate and predictable results. In the future, it is necessary to conduct research on the development and optimization of forecasting models, as well as introduce new analysis methods. The use of digital platforms and models allows for more efficient resource management and project financing. In the future, it is worth focusing on the development of adaptive models for resource forecasting. Integrated methods and technologies provide effective management of the configuration of project products, which requires the creation of analytical tools based on computational intelligence. Based on the analysis of theoretical and practical aspects, it was established that the post-war restoration of the transport and security infrastructure of rural communities is a priority task. This is due to significant destruction as a result of hostilities. For effective restoration and modernization of security infrastructure, it is necessary to implement relevant projects with comprehensive management and development of specialized management tools.

Table 2. Management tasks and tools for rural community infrastructure restoration projects

1. Task: Assess the state of the project environment
- Tools: SWOT analysis, PESTLE analysis, environmental element forecasting models. - Technologies: Geographic information systems (for collecting geographic data, machine learning algorithms.
2. Task: Assess available resources and funding sources
Tools: Resource matrix analysis, budget analysis, resource status assessment models. - Technologies: Financial analysis platforms, electronic platforms for financial planning.
3. Task: Coordination of project product configuration
- Tools: System alignment method, product integration methodology, configuration modeling. - Technologies: Data mining, computational intelligence for logistics optimization.
4. Task: Alignment of the project with the current state of the environment
- Tools: Configuration Agreement Method, Project Management Methodologies (PMI, PRINCE2). - Technologies: Using drones and computer vision for monitoring, decision support systems.
5. Task: Develop a project management plan
- Tools: Gantt charts, PERT methods, budget and time planning tools. - Technologies: Software tools for real-time collaboration, systems for decision support.
6. Task: Risk identification and assessment
Tools: Risk matrix, sensitivity analysis, decision tree. - Technologies: Using computational intelligence to predict risks and minimize them.
7. Task: Assessing value for stakeholders
- Tools: Stakeholder requirements analysis, value matrix, project impact prediction models. - Technologies: Online feedback platforms, computational intelligence for data analysis.

Source: authors development

For the successful implementation of transport and security infrastructure restoration projects, it is necessary to solve a number of scientific and applied problems related to individual project characteristics. These problems were formulated and management tools were outlined that should be developed for project managers in order to effectively solve the tasks set.

The formulated management problems are the basis for creating tools that will be used during the implementation of infrastructure restoration projects. Further research should focus on the development of accurate models for predicting the components of the project environment and their interaction. Adaptive models will provide more accurate forecasting and more effective resource management. The implementation of the developed analytical tools based on computational intelligence will allow integrating intelligent technologies into the management process. The development of innovative tools should be based on the use of modern computational intelligence technologies to solve forecasting and risk management problems.

It is necessary to rethink the approach to project management in various sectors of the economy. The development of project management has gone through several stages related to the development of

classical methods and tools, such as Gantt charts, PERT charts and the critical path method (PERT/CPM).

A recovery project management methodology does not have to be pure Waterfall or Agile. In some cases, it is advisable to use a combined approach, taking the most effective components from each methodology for each of the project stages. Thus, quite often in project management, cascade methodologies are used for the stages of requirements analysis, design and development of the technical task, and flexible methodologies are used for the subsequent stages of development, testing and support (Agile Vs Waterfall: Know the Difference Between Methodologies https://www.guru99.com/waterfall-vs-agile.html). Hybrid methodologies are also used, when overall project management is carried out using the waterfall methodology, but for some stages it is supplemented with other frameworks. For example, the V-model is used for government projects, in which a significant proportion of tasks for testing is simultaneously developed at the stages of analysis and design, which is a violation of the classic cascade approach (When to Choose Waterfall Project Management Over Agile https://www.smartsheet.com/when-choose-waterfall-project-management-over-agile). But in any case, the choice of a pure or combined methodology should be made through a formal analysis of the project and the available opportunities for its implementation, in order to minimize the influence of the subjective preferences of decision-makers.

To choose a project management methodology, it is suggested to evaluate the project in the following areas: resource availability; determination of requirements for project results; the complexity of the project.

The direction of resource availability includes such assessments as the customer's budget limitations, the ability to manage the deadlines for the completion of stages and the project as a whole, the ability of the executor to provide specialists for all stages of the project, taking into account time and budget constraints. It is proposed to assess the resource availability of the project according to the criteria are shown in Table 3.

In the event that the customer knows exactly what result he needs as a result of the implementation of the project and can clearly formulate all the requirements, it is possible to calculate the project budget with sufficient probability. In such a situation, the budget is strictly limited to the total amount specified in the contract. The opposite situation is the implementation of a project with elements of free search, when it is not clear which solutions will bring the best result. That is, during the implementation of the project, the hypotheses are checked and the requirements for the results are clarified. Intermediate options may include minor budget changes (about 5-10% of the total project cost) or the possibility of adjusting the budget depending on the expected result, when one of several previously described options is chosen during the project implementation process.

The criteria for evaluating deadlines are similar to the budget criteria. In the case of a simple project or a project that is a replication of previously implemented ones, the deadlines for each stage can be determined with maximum accuracy. Usually, in such cases, the customer expects to receive the result according to the schedule. Complex projects, in which there is a high probability of unforeseen situations, require the establishment of adaptive completion dates for each stage, taking into account possible difficulties and leaving reserves of time to adapt to new clarifications. Intermediate options may include timing changes of up to 5% for each stage, with 10-15% deviations for stages requiring research and clarification of objectives, and 5-10% for other stages.

Table 3. Criteria for assessing project resource availability

Criteria	**The customer's budget**			
	Strictly limited	**May vary within minor limits**	**May vary slightly depending on the expected result**	**Fully adaptive to the expected result and profitability**
Rating	1	2	3	4
Criteria	Deadline			
	Strictly limited	May vary within minor limits	May vary slightly depending on the expected result	Fully adaptive to the expected result and profitability
Rating	1	2	3	4
Criteria	Provision of executors			
	The performer cannot quickly increase the number or change the structure of the team	Additional specialists may be involved to solve some tasks	The team can change when the load changes within 20-30%	The contractor has significant working resources to expand the team of contractors when changing tasks and expanding the scope of work
Rating	1	2	3	4

Source: authors development

Another important criterion for assessing project resource availability is the presence of executors. If the executor is a small company with a limited number of projects, he will not be able to quickly adapt to changes in goals and objectives. In contrast, a large outsourcing company that works on many projects at the same time and has a large pool of developers can strengthen the project team depending on the need for experts in different specializations. Intermediate versions of this criterion may include hiring 1-2 specialists to perform specified tasks or significantly strengthening the team by 20-30% of working time.

The assessment of the certainty of the requirements for the project results includes the assessment of the novelty of the project for both the customer and the executor, as well as the degree of certainty regarding the consumers of the product and their needs, which must be taken into account during marketing research for the product to enter the market. Thus, the assessment of the certainty of the requirements helps to understand how complete and complete the technical terms of the project will be and whether it will be possible to implement the project according to the cascade methodology.

It is proposed to assess the determination of the requirements for project results according to the criteria are shown in Table 4.

Table 4. Criteria for evaluating the definition of requirements for project results

Criteria	**The degree of novelty of the product for the customer**			
	The customer has already used similar products	**The customer has some experience working on projects in this area**	**The customer has experience in a related field, but has no experience working on such projects**	**The product is completely new for the customer**
Rating	1	2	3	4
Criteria	The degree of novelty of the product for the performer			
	The contractor has already developed similar products	The contractor has some experience of working with similar technologies and similar products	The contractor has experience in a related field, but does not have experience working on such projects or with the technologies required for implementation	The product is completely new to the artist
Rating	1	2	3	4
Criteria	The degree of certainty of the needs of the consumer of the product			
	The needs are fully researched and described, the presence of needs is confirmed by the demand for similar products	Conducted needs research on a relevant sample of consumers	Conducted needs research on a small group of consumers	There is only a hypothesis about the needs of consumers
Rating	1	2	3	4

Source: authors development

The first option for the degree of novelty of the product for the customer is a completely familiar product. In this case, the customer already had experience with a similar product and actually orders a new version that uses new technological capabilities, or an enhanced version of an old product that he knows well. The opposite case is the situation when the customer is faced with a problem that he wants to solve with the help of a software product, but does not have experience with similar solutions and is not familiar with the practices of competitors in this area. Intermediate options include a customer

who has some experience in projects in this area, as well as a customer who is familiar with a nearby field but has no practical experience with such projects.

The criterion of the degree of novelty of the product for the performer also has several options. The first of them is a product that is already familiar to the performer, because he previously developed similar solutions with the same functions and technologies. The opposite is a completely new product that requires the implementation of technologies that the developer team is unfamiliar with, its functionality is unknown to the testers, and the subject area is generally new to the developer. Intermediate options include cases where the contractor has some experience with similar technologies and related products, or when he is familiar with a related field but does not have experience working on exactly such projects or with the required technologies.

According to the criterion of the degree of certainty of the consumer's needs, the simplest option is a situation when the needs are fully studied and described, and their existence is confirmed by the demand for similar products. This is usually possible when the customer and the consumer coincide, or when the product is developed for an already well-researched subject area in which similar products exist.

The degree of uncertainty increases if needs research is conducted on a relevant sample of consumers, but the customer is not the final consumer of the product. In this case, there is a higher probability of the occurrence of additional conditions and needs during the implementation of the project. Even greater uncertainty arises when the technical task is formed on the basis of researching the needs of only a small group of consumers, since unforeseen situations may arise at the stage of practical implementation of the project. Finally, the highest degree of uncertainty is observed in projects that are based only on hypotheses about consumer needs. In such a case, the implementation of the project should include customer research and multiple iterations of the technical task development cycle, which makes it possible to implement the project only with the help of a flexible methodology.

In the direction of the complexity of the project, it is estimated how many specialists of different specializations need to be involved for implementation, whether the consumers of the future product are homogeneous, how many problems the product solves and how many modules it contains, as well as how critical errors can be during the implementation of the project and how deep the testing should be. Therefore, the complexity of the project reflects the probability of deviations from the implementation plan and the importance of constant communication to clarify requirements during the development process.

It is proposed to evaluate the complexity of the project according to the criteria are shown in Table 5. When assessing development complexity, it is important to first analyze the level of communication complexity between different groups in the development team during project implementation. The first evaluation option assumes the maximum simplicity of the product, when all roles and tasks can be defined before the start of development, and the need for communications between groups is minimal. The next level of complexity occurs when the product is relatively simple, but some tasks need to be clarified during the transition from one stage to another, which requires communication between different specialists in the team. Next comes the level at which the customer's involvement in communications is necessary during the transition between stages, i.e. the product requires frequent coordination with the customer and active communication between development groups. The highest degree of complexity is observed when the product cannot be developed according to the cascade

methodology, as it requires a regular return to previous stages, as well as constant communication both between groups of specialists and with the customer.

Table 5. Criteria for evaluating project complexity

Criteria	**Complexity of development**			
	The product is easy to develop, all roles and tasks can be defined before development begins	**The product is easy to develop, but some tasks need to be clarified during the development process**	**The product requires frequent coordination with the customer and communication between development groups**	**The product cannot be developed in stages, without returning to previous stages, it needs regular communication**
Rating	1	2	3	4
Criteria	The complexity of the problem to be solved			
	The problem is simple, has a linear solution algorithm	The problem has a linear solution algorithm and two or three layers	The problem is non-linear, but does not have a large number of components and strata	The problem is complex and consists of solving many strata that have complex connections between them
Rating	1	2	3	4
Criteria	The cost of service interruptions and errors			
	Errors and delays in the service are not critical	Service interruptions do not lead to significant financial losses, but can provoke consumer rejection	Service interruptions and errors have a large negative impact	Errors are categorically unacceptable (financial products, management of objects on which human life depends, etc.)
Rating	1	2	3	4

Source: authors development

The assessment of the complexity of the problem is related to the analysis of how difficult it will be to create a technical task for the project and implement it without changes. The more complex the problem, the less likely it is that all possible issues will be foreseen, which makes it difficult to implement the project according to the cascade methodology. If a problem has a linear solution algorithm and only one goal, it can be considered simple. The next level of complexity occurs when a product solves a problem with multiple paths and achieves multiple consumer goals, but all of them have a linear solution algorithm. A higher difficulty score is given to projects in which the problem is

non-linear, even though the problem itself does not contain a large number of components. The highest level of complexity is characteristic of complex problems that include many strategies with complex relationships.

In the context of the cost of service interruptions and errors, it is suggested to distinguish between degrees of product importance. At the first level, minor errors and delays are not critical, for example, when a product periodically provides secondary information to consumers who do not have inflated expectations. The next level includes situations where interruptions in service do not lead to significant financial losses, but can cause an outflow of consumers to competitors. A product whose disruptions have a significant negative impact and can lead to financial losses for the owner has a higher importance rating. The highest degree of importance is characterized by the absence of errors, as in the case of financial products, banking applications or software, on which people's lives depend or which can cause accidents and disasters.

Conclusions

In the post-war period, the restoration and modernization of the infrastructure became a priority. This is due to the fact that as a result of hostilities and secondary impact factors, a large part of the infrastructure was damaged or destroyed. For the successful implementation of restoration and modernization projects, it is necessary to implement system management, which includes hybrid technologies and appropriate management tools.

The proposed model of hybrid management of infrastructure restoration projects in the post-war period singles out three main components: resource availability, clarity of requirements for project results, and project complexity. Appropriate assessment criteria have been developed for each of these components, which form the basis for determining the features of management processes in these projects. We analyzed the components of infrastructure restoration projects and identified the interrelationships between their indicators. Post-war reconstruction projects were found to operate in a common project environment and shared resources.

The use of hybrid management models will ensure effective cooperation between teams involved in recovery in different sectors of the economy. This will be especially important for organizing interactions not only within the project team, but also with the team responsible for ensuring sustainable development.

References

1. Ivanov S.V. (2019). Economic recovery and development of countries after armed conflicts and wars: unmissable opportunities for Ukraine. Economy of Ukraine. No. 1 (686), 75-89.
2. Priymakova Yu. A. (2020). Investment and innovation processes in Ukraine: current state and changes in the post-conflict period. Business Inform. No. 5, 117–128. DOI: https://doi.org/10.32983/2222-4459-2020-5-117-128 (access date: 12/15/2022)
3. Krupa M., Hajek J. (2022). Hybrid Project Management Models: A Systematic Literature Review. International Journal of Project Organisation and Management. DOI: https://doi.org/10.1504/IJPOM.2024.10056237

4. Serrador P., Pinto J. K. (2015). Does Agile work? – A quantitative analysis of agile project success. International Journal of Project Management. Volume 33. Issue 5, 1040–1051. DOI: https://doi.org/10.1016/j.ijproman.2015.01.006
5. Bushuev S., Kozyr B. (2020). Hybridization of infrastructure project and program management methodologies.Herald of the Odessa National Maritime University. P. 187–207. DOI: https://doi.org/10.47049/2226-1893-2020-1-5-26
6. Zvarych I.T., Zvarych O.I. (2017). Modern approaches to the methodology of managing projects of sustainable development of the region in the context of continuous education of civil servants. Bulletin of the Kyiv National University of Technology and Design. Series: Economic Sciences.. No 5, 11–23. URL: https://er.knutd.edu.ua/bitstream/123456789/8544/1/V115_P011-023.pdf
7. Azenha, C. F., A. D. Reis, and L. A. Fleury. (2021). The Role and Characteristics of Hybrid Approaches to Project Management in the Development of Technology-Based Products and Services. Project Management Journal 52 (1): 90–110.
8. Gemino, A., B. Horner Reich, and P. M. Serrador. (2021). Agile, Traditional, and Hybrid Approaches to Project Success: Is Hybrid a Poor Second Choice? Project Management Journal 52 (2): 161–175. https://doi.org/10.1177/8756972820973082
9. Agile Vs Waterfall: Know the Difference Between Methodologies https://www.guru99.com/waterfall-vs-agile.html
10. When to Choose Waterfall Project Management Over Agile https://www.smartsheet.com/when-choose-waterfall-project-management-over-agile
11. Smith, J., Taylor, A. (2023). Monitoring Infrastructure Recovery Using Drones and Computer Vision Technology. Journal of Civil Engineering, 15(2), 112-128.
12. Jones, L. (2022). SWOT and PESTLE Analysis in Post-War Infrastructure Projects. International Journal of Strategic Management, 28(4), 67-81.
13. Williams, K., Peterson, D. (2020). Resource Matrix Analysis for Effective Financial Planning in Infrastructure Projects. Financial Management Review, 19(3), 201-215.
14. Brown, S., Davis, M. (2021). Integration of Project Products Using Computational Intelligence for Logistics Optimization. Journal of Project Management, 13(1), 145-160.
15. Evans, T., Garcia, P. (2020). Real-Time Collaboration Tools for Efficient Project Planning in Infrastructure Recovery. Technology and Project Management, 11(5), 78-95.
16. Chen, X., Lee, H. (2021). Risk Prediction in Recovery Projects Using Computational Intelligence Techniques*. Risk Management Journal, 22(3), 123-138.
17. Roberts, S., White, R. (2022). Stakeholder Value Assessment in Post-War Infrastructure Projects: A Case Study Approach. Journal of Business Strategy, 18(2), 215-230.
18. Nelson, J. (2021). Leveraging Online Platforms for Stakeholder Feedback in Infrastructure Recovery Projects. Journal of Digital Business, 9(4), 89-102.
19. Popova, O., Chechel, A., Fomina, O., Myroshnychenko, G., Medvedieva, M., Hoholieva, N., ... & Molodchenko, O. (2023). ASSESSMENT OF RELATIONSHIPS BETWEEN SMART TECHNOLOGIES, CORPORATE SUSTAINABILITY, AND ECONOMIC BEHAVIOR OF COMPANIES. *Eastern-European Journal of Enterprise Technologies*, *122*(13).

Chapter 2 Digital technologies and sustainable development

ARTIFICIAL INTELLIGENCE IMPLICATION IN ENSURING EFFICIENT USE OF LIMITED RESOURCES

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Abstract

The state, features, and prospects of implementing AI for energy-efficiency usage of limited resources were studied, and the willingness of household consumers to use AI technologies to increase the efficiency of energy resource consumption was determined through a survey. It is summarized that the issue of effective use of limited resources in the example of consideration of energy resources corresponds to the current state of development of both the economy and the activities of individual enterprises and household energy consumers. The experience of using AI to improve energy efficiency management is highlighted, and the main elements of Smart Grid are identified, which will allow for the integration of AI through the development of neural networks in the energy supply processes and control of the level of energy resources usage. A neural network model has been developed, which, because of integration into the Smart Grid, will improve the process of obtaining information about energy consumption and making decisions about energy efficiency management. 121 respondents were analysed based on the survey's results regarding their willingness to use energy-saving and digital technologies in their apartments. It was concluded that despite the weak readiness and initiative to use digital technologies to ensure energy efficiency among household consumers, for the energy sector, the issue of using AI is critical and requires additional attention, in particular, practical cases of the neural networks use in the processes of ensuring energy efficiency.

Keywords: *artificial intelligence, technology, energy efficiency, smart grid, neural networks, energy resources.*

Introduction

The growth of the world's population and the active development of countries' economies lead to an increase in the need for resources, such as water, metals, other raw materials, and energy. However, limited resources and environmental challenges require a new approach to their consumption. Effective use of limited resources has become a key issue for states, businesses, and society. By limited resources, we consider resources that are finite or difficult to obtain. This means that they cannot satisfy all the needs of society in an unlimited amount, so there is a need to distribute them optimally. Allocation of limited resources is one of the main problems of the economy since people's needs always exceed available resources. Therefore, the efficiency is a determining criterion for their use, which involves not only the rational management of resources, but also the reduction of their consumption and the introduction of innovations that will help preserve resources for future generations. This is driving a rapid transformation of the energy sector amid increased demand for sustainable resource use, and energy efficiency is an integral part of the changes. The International Energy Agency in its reports emphasizes, that energy efficiency is called the “first fuel” in clean energy transitions, as it provides some of the quickest and most cost-effective CO_2 mitigation options while lowering energy bills and strengthening Energy security (IEA, 2024). Investigators also pay attention (Mychajlyshyn et al., 2024) that energy efficiency must also be considered from the perspective of additional sources of energy, as it contributes to reducing the consumption of both traditional and renewable energy sources. Thus, energy efficiency is an energy resource possessed by all countries without exception, which is based on the transformation of the energy resource consumption concept and meets the conditions of the energy transition. Digital transformation, particularly with the help of artificial intelligence (AI), can significantly improve energy efficiency by optimizing energy consumption, automating control systems, and predicting maintenance needs. AI-powered analytics identify inefficiencies, enabling accurate energy demand forecasting and load management. Automation of energy-intensive processes increases the efficiency of buildings, transport, and production. AI-powered predictive maintenance minimizes downtime and energy loss due to equipment wear and tear. In addition, AI facilitates the integration of renewable energy sources, ensuring a stable balance between energy demand and supply. Together, these programs help reduce energy costs and support the transition to sustainable, clean energy systems.

Previous studies on the subject

Previously, the issue of energy efficiency management was studied by many scientists. This issue was considered in the paper (Polyanska et al, 2024), where it was stated that energy efficiency management encompasses the development and implementation of measures aimed at enhancing energy efficiency across all facets of an organization’s operations, involving planning, financing, management, and oversight. A comprehensive approach is crucial to ensure energy efficiency management, focusing on adopting energy-efficient technologies, optimizing energy consumption in various domains, and fostering a culture of energy efficiency within society. For effective energy efficiency management of an organization, it is important to implement measures to enhance energy efficiency that correspond to its size, goals, and objectives. In other words, the larger the organization, the more global the task

of managing energy efficiency, and its prioritization is advisable. It is important to consider at which level the organization's energy efficiency management is situated, as this will enable its quality integration into the global energy efficiency management system and more effectively control and monitor the results. Energy efficiency management can be considered at various levels, including global, macro-level, meso-level, micro-level, and individual.

Energy efficiency management operates across various levels, each with specific objectives and strategies: global level focuses on establishing international agreements, conventions, and shared goals to guide countries worldwide in enhancing energy efficiency; the macro level involves crafting national energy strategies and regulatory policies that encourage energy-efficient practices; the mezo level targets the development of regional energy programs and the promotion of local energy efficiency initiatives; the micro level centres on implementing tailored energy programs for businesses, organizations, and households; individual level relies on personal choices and actions to conserve energy. Adopting a comprehensive approach to energy efficiency across these interconnected levels yields significant advantages, such as reducing dependency on energy imports, lowering greenhouse gas emissions, and cutting energy costs.

The increase in energy efficiency requires not gradual transformations but cardinal changes in relation to the production, distribution, and consumption of power-energy resources. For the positive decision of this task, it's necessary to connect the near-term macroeconomic decisions with overcoming the barriers, which consist in the absence of stimulant measures for effective use of energy, overcoming the so-called "failures of market", incomplete information, influence of negative external factors, high transaction charges and absence of financing (Mayssner et al, 2012). Enterprises must make these decisions in the context of introducing the energy management system, introducing the newest technologies, and activating work in relation to bringing in investors in the sphere of energy efficiency (Polyanska, 2014).

Artificial intelligence (AI) has become one of the most discussed technologies of the 21st century, changing all aspects of our lives - from industry to communications, medicine, etc. (Golaw, 2022). Every year, investments in the development of AI technologies grow, and more and more countries and private companies allocate large budgets for their development.

According to a study by Stanford University (USA), global corporate investment in AI has grown significantly in recent years, with more than 189 billion US dollars invested in 2023 alone (Fig. 1). The largest investor countries are the USA, China and the countries of the European Union. According to Goldman Sachs, global investment in AI will reach $200 billion by 2025. USA. However, for large-scale transformation to occur, businesses must make significant initial investments in physical, digital and human capital to acquire and implement new technologies and change business processes (Goldman Sachs, 2023).

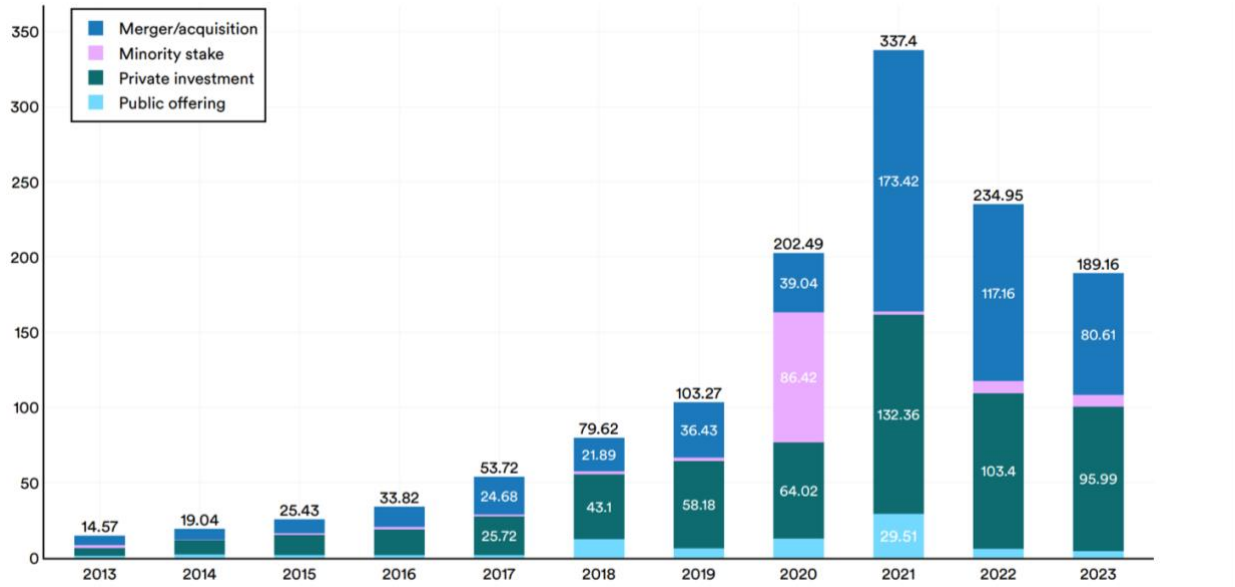

Fig. 1. Global corporate investment in AI, 2013-23, billions of U.S. dollars
Source: Artificial Intelligence Index Report, 2024

Although investment in artificial intelligence in general continues to grow, private investment specifically in AI for the energy sector, in particular oil and gas, shows a downward trend (Fig. 2). At the same time, other areas receive significantly more support. The sharp increase in investment in AI infrastructure, research, and management reflects the strategic potential of these technologies for economic development and competitiveness. It is important to note that when using neural networks, the use of networks has given experience that has already been accumulated during the current period of use. Their properties were investigated, and key characteristics such as the amount of information, the number of neurons, the number of epochs, and accuracy. There are different areas of implementation that form different configurations of networks and allow implementing solutions to practical problems, such as pattern recognition, classification, selection, control, and others.

Investments in AI in the energy sector peaked around 2021, which began to decline and reached $1.47 billion in 2023 (Fig. 3).

The development of AI technologies, digital technologies, and automation are increasingly integrated into various sectors of economies, which opens new opportunities, particularly in implementing approaches aimed at achieving maximum efficiency in conditions of limited resources. Thus, in further studies of energy efficiency, it is important to consider the development of new technologies from the point of view of the possibilities of their use to increase energy efficiency at all levels of energy efficiency management.

Artificial intelligence technologies for improving energy efficiency were studied by scientists in their article (Olatunde et al., 2024), who confirmed that these technologies can analyse large data sets, in particular, to identify patterns and trends, which in turn provides even more accurate control and forecasting of energy demand. In addition, (Olatunde et al., 2024) stated that the main advantage of AI in increasing energy efficiency is its ability to learn from data and adapt, which contributes to the continuous improvement of energy-saving strategies. Artificial intelligence algorithms can optimize

energy consumption based on factors such as weather conditions, energy prices, etc., resulting in significant cost savings and environmental benefits.

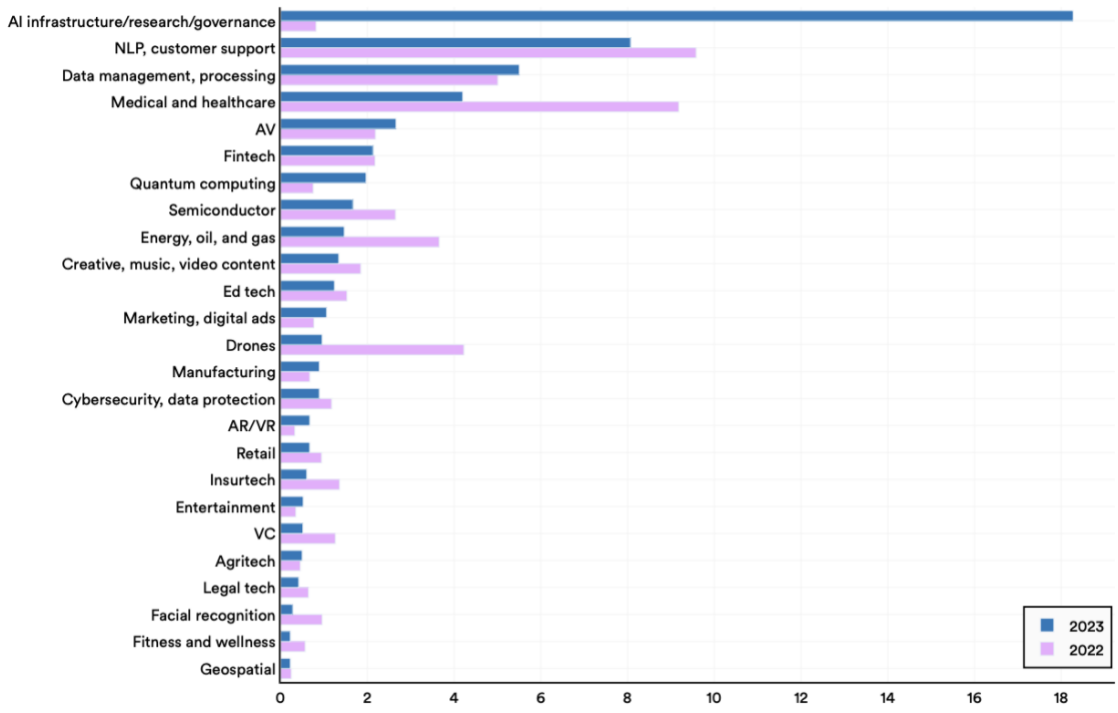

Fig. 2. Private investment in AI by focus area, 2022 vs. 2023, billions of U.S. dollars
Source: Artificial Intelligence Index Report, 2024

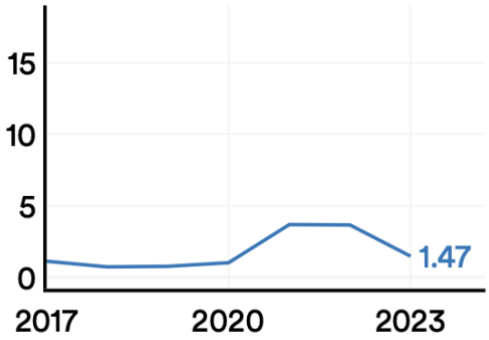

Fig. 3. Private investment in AI, 2017–23 (energy, oil, and gas), billions of U.S. dollars
Source: Artificial Intelligence Index Report, 2024

Based on the characteristics of neural network formation components, (Psiuk & Polyanska, 2024) considered the model of the integration of neural networks into the information system of the mining enterprise. The architecture of this information system is structured into four distinct zones: a corporate zone, an operational zone, a control zone, and an intermediate zone. Each zone serves a specific function, ensuring seamless interaction and data flow within the system while supporting the implementation of neural network technologies.

Significant progress in AI and automation technologies contributes to implementing these technologies and to the effective energy transition of cities based on increased energy efficiency. In this way, the latest developments in artificial intelligence provide automated tools for the design, analysis, modelling, monitoring, diagnosis, and supply of energy in cities. These tools can distribute energy resources and manage demand and supply to ensure the efficiency and economy of the network, which is especially relevant during the active expansion of RES capacities that generate electricity unevenly (Farzaneh et al., 2021). A rather promising application AI in cities is the spread of smart buildings equipped with numerous sensors and other intelligent tools for monitoring and managing energy consumption. Equipping homes with such sensors can be extremely effective for energy efficiency goals based on real-time AI use of data (Farzaneh et al, 2021).

The concept of "green" or sustainable construction was discussed in Ukraine even before the start of the war in the context of international and European initiatives and regulatory documents. This idea involves using the latest energy-efficient technologies during construction, which contributes to more efficient use of resources during the operation of buildings. Special attention is also paid to the issue of reducing carbon dioxide emissions during the construction and operation of housing. Smart construction integrates these principles with modern digitalization trends. Today, four main directions support construction with zero carbon emissions: decarbonization, electrification, energy efficiency, and digitalization. (World Economic Forum, 2021). These trends work in the way to reduce carbon emissions and optimize costs for construction processes and supporting infrastructure. Achieving zero CO_2 emissions in buildings (or creating an opportunity to achieve it) can be achieved by moving away from fossil fuels for heating, switching to renewable energy sources both on-site and off-site, reducing the use of refrigerants with high global warming potential and the use of low-carbon, recycled or reused materials.

Climate change is expected to increase the demand for electricity: in regions that previously did not need air conditioning, the need to reduce the heat load will now increase. Conversely, unexpectedly cold weather can increase electricity consumption even in warm areas. In certain situations, this will lead to additional costs for homeowners, as fossil fuels are often kept cheaper through subsidies, and additional investment in grid infrastructure will be required to meet growing energy demand, including generation, transmission, distribution, and management of more volatile renewables.

To achieve energy efficiency, it is important to combine both passive and active measures, namely: passive measures such as reinforced insulation and high-efficiency equipment can reduce the overall demand for electricity. At the same time, proactive efficiency measures, including automatic demand response and dynamic energy optimization, can ensure demand flexibility in line with intermittent renewable generation. Digitalization is an important means of energy efficiency and demand flexibility in buildings. Smart buildings take advantage of advanced sensing and control, system integration, data analytics, and energy optimization to proactively reduce energy use and demand and improve occupant comfort, health, performance, and facility sustainability. Embedding these digital capabilities into "smart" equipment and appliances provides additional benefits, including improved reliability and remote control in addition to reduced energy consumption and emissions (Polyanska et al, 2023).

PassivDom is a Ukrainian startup that designs and builds modular homes that do not require an external energy source. These buildings are created using 3D printing technology. The founder of the startup, Maksym Gerbut from Mariupol, has developed houses with high energy-saving characteristics and

intelligent functions. The frame of the building consists of a monolithic part, which is formed step by step with the help of large manipulator robots, like 3D printers. However, unlike conventional 3D printing, PassivDom uses different materials to build walls, ceilings, and roofs, including carbon fiber or fiberglass filaments, which add extra strength to the structure (Polyanska, Cichoń, Mykytuk, 2023).
It is appropriate to note that the transition to new progressive technologies of energy-efficient construction should also consider motivational changes due to social technologies (Deloitte, 2013). This change will lead not only to a technical revolution but also to major changes for energy consumers. To maintain and grow their customer base, utilities must adopt a new strategic approach to customer engagement to increase their participation in smart change.
Recent studies also indicate a significant evolution from traditional energy consumption analysis methods to sophisticated AI-driven methods, thus facilitating the energy management decision-making process (Ohalete et al, 2023). Scientists consider the issue of using artificial intelligence to increase energy efficiency not only in the direction of household consumers but also in the direction of manufacturing companies (industry). For example, implementing AI in industrial enterprises can detect deviations in consumption in real-time and identify inefficient use of energy resources. Also, using data analysis, AI can predict wear and tear of equipment, and thus ensure timely maintenance and minimize energy losses, etc. (Narciso & Martins, 2024)
However, the implementation of AI technologies in energy has challenges, which are significant obstacles. In the article (Ahmad et al., 2022), scientists noted that among technological aspects, the bottleneck is often the setting of synchronous operation of new equipment with existing equipment. There is also a need to update the existing protocols (before the introduction of AI), which will allow the coordination of the work between new and old equipment while ensuring the economically beneficial operation of the system. Another problem that scientists are paying attention to is related to ensuring fast and efficient integration of data from different sources while ensuring adequate data protection in the energy industry. In addition, it is important to understand that although AI technology is quite deeply developed, its adaptation in various industries, such as energy, still requires significant refinement and deepening of understanding, which further creates the problem of slow implementation by energy companies, as well as significant time and financial costs. Despite many obstacles, one of the main ones is the need to ensure the constant growth of technical capacities to ensure the effective operation of AI in the conditions of a constant increase in the volume of data flows and the complexity of algorithms (Ahmad et al., 2022).
Summarizing the above, this publication aims to investigate the state, features, and prospects of using AI for energy-efficient use of limited resources, as well as to determine the readiness of household consumers to use AI technologies to increase the efficiency of energy resource consumption. To achieve this goal, the following tasks have been defined:

- to study the works of scientists who investigated the issue of effective use of limited resources on the example of consideration of energy resources;
- explore the experience of using AI to improve energy efficiency management;
- develop a neural network model that, as a result of integration into the Smart Grid, will improve the process of obtaining information about energy consumption and making decisions about energy efficiency management;

- to analyse the results of a survey of respondents regarding their readiness to use energy-saving and digital technologies in their apartments.

The results

Energy efficiency can be significantly enhanced through the application of AI technologies. With recent advancements in manufacturing, more energy sources have become accessible, paving the way for optimized energy use. Managing and operating extensive power grids has become increasingly complex, but AI enables rapid processing of large datasets, which enhances the reliability and performance of these energy sources. This has contributed to the rise of smart grids designed to integrate multiple energy sources and manage them efficiently. Smart grids improve overall energy utilization by dynamically coordinating and adjusting the operation of diverse energy sources (Tanveer, 2022). Thus, ensuring energy efficiency at enterprises and for household consumers is expedient to develop and implement in accordance with modern technologies and conditions of the Smart Grid system. A smart grid is an energy supply network that is built and functions based on the use of IT technologies (Dänekas et al, 2014). Modern IT technologies integrated into the Smart Grid allow the processing of a significant array of information, which is the basis for developing artificial intelligence algorithms (Fig.4).

The article proposes the architecture of the SGAM model (CEN-CENELEC-ETSI Smart Grid Coordination Group, 2012), which in our work is supplemented with neural network modules that can be used to improve the conditions for compliance with the smart grid concept. Neural networks make it possible to increase the efficiency of data processing and decision-making based on them. Figure 2 presents the architecture of the neural network modules system for the information structure of the smart grid system in the field of energy supply, which is focused on increasing energy efficiency. To describe the architecture of neural networks for ensuring energy efficiency in smart grid systems, let's take a closer look at the functional level, which is responsible for the task of efficient use of resources. Fig. 5 presents the sectors that are involved in the transmission of electricity, as well as areas of operational activity (location, station, enterprise, processes, office, market). Arrows show communication (information transfer) with neural network modules. Within the presented modules, the types of input information and the obtained results are presented, which provide conclusions based on the processed data regarding the achievement of the level of energy efficiency.

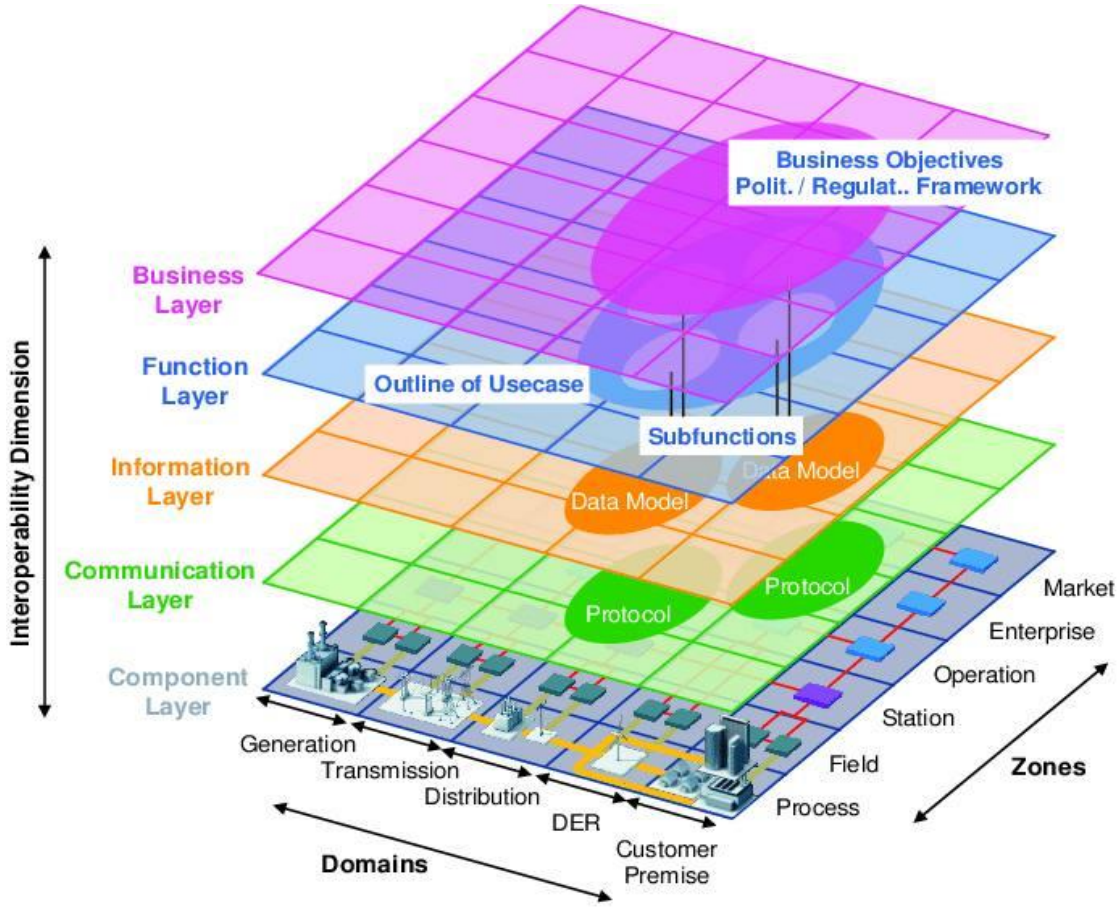

Fig. 4. Smart Grid Architecture Model (SGAM)
Source: Smart Grid Coordination Group, 2012

Models of the proposed architecture of neural networks for smart grids are described in more detail. The Demand Forecasting Module predesignates to predict energy demand and provide insights into seasonal and hourly consumption patterns. It gathers data from smart meters, weather APIs, and historical consumption logs from the customer premises and distribution nodes. By leveraging this data, the model adjusts forecasts based on sudden changes in weather or unexpected consumption spikes, helping to reduce reliance on peaking power plants and ensuring efficient energy allocation and distribution among consumers.

The Load Balancing and Resource Allocation Module is designed to optimize grid performance by dynamically adjusting the flow of electricity across different regions. It uses a combination of grid load data, transformer performance, and DER output to make real-time resource allocation decisions. This module ensures that distributed resources are efficiently utilized, adjusting power flow to prevent congestion and minimizing energy losses. Additionally, it can communicate with storage systems to release or store energy as needed, maintaining grid balance during peak periods, stabilizing the consumption curve when switching to different work regimes, and directing energy to specific areas if necessary.

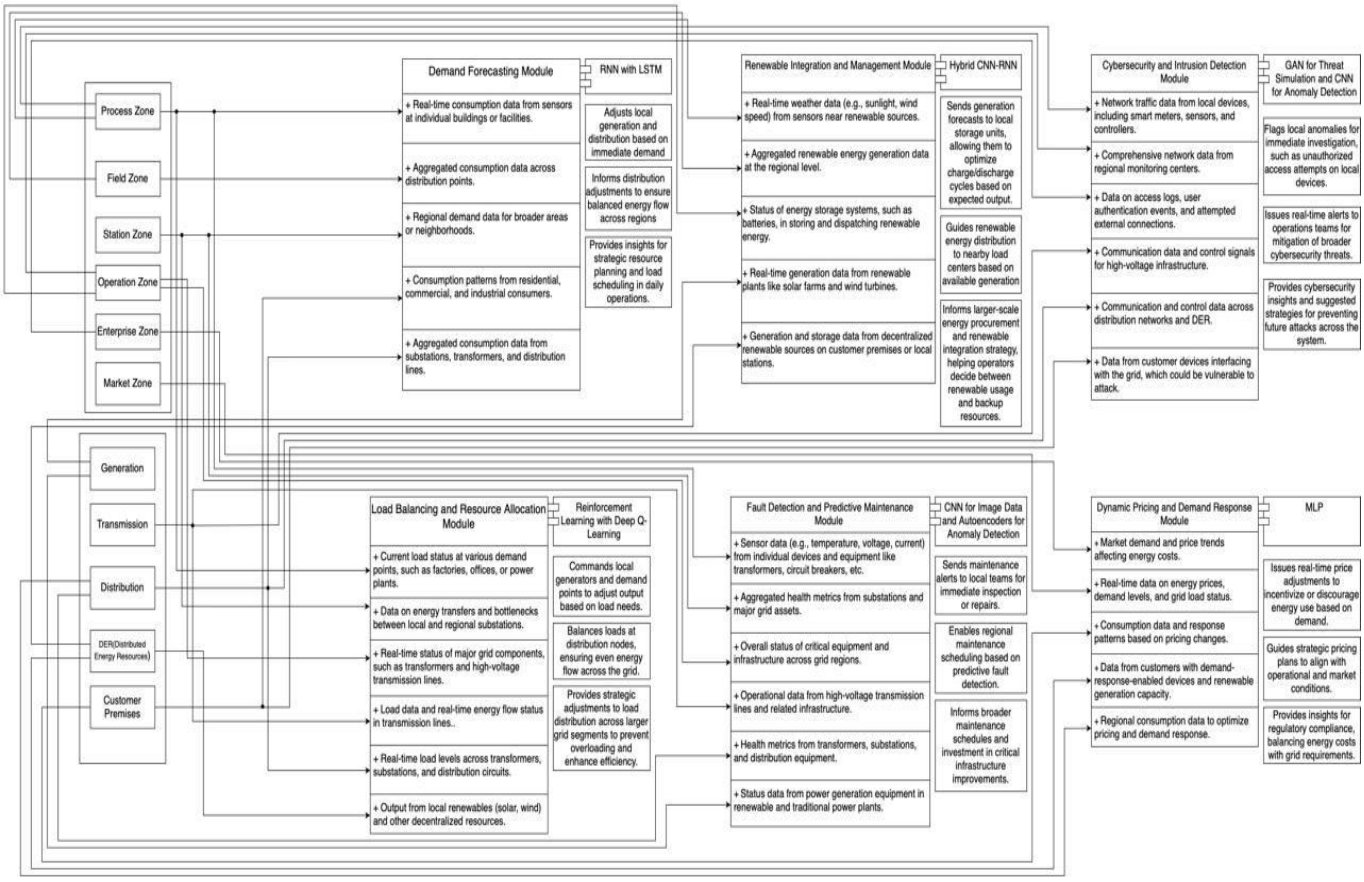

Fig. 5. Architecture description of sectors that are involved in the transmission of electricity and operational activity

Source: completed by authors

The Renewable Integration and Management Module focuses on seamlessly integrating solar, wind, and other renewables into the energy grid. It analyses data from meteorological stations, energy storage systems, and DERs to forecast renewable generation. The module adjusts grid operations based on predicted generation, optimizing the use of batteries and other storage solutions to smooth out variability in renewable energy output. This proactive approach helps reduce renewables' curtailment and maximizes green energy while maintaining grid stability.

The Fault Detection and Predictive Maintenance Module is crucial for maintaining the health of grid assets. It continuously monitors data from process-level sensors attached to equipment like transformers, circuit breakers, relays, and substations. By using autoencoders to detect deviations from normal operating conditions, the module can identify potential faults early, triggering maintenance actions before failures occur. This reduces downtime, extends the lifespan of equipment, and lowers maintenance costs by allowing for targeted interventions rather than blanket inspections. Also, it can analyse critical system failures, how capable the system is of sustaining loads and recovery, and scheduled replacement of components.

Additionally, it is possible to note the need to form specialized service groups, which are needed to maintain various network functions in different situations.

The Cybersecurity and Intrusion Detection Module provides a proactive defence mechanism against cyber threats targeting the smart grid's communication networks. It uses deep learning models trained

on historical network traffic data to detect anomalies that could indicate potential attacks. This module integrates with the grid's operational and market zones, monitoring both internal data exchanges and external interactions with market operators. The system can quickly isolate affected nodes and reroute communication to ensure the grid remains secure and operational during a cyber incident.

The Dynamic Pricing and Demand Response Module plays a key role in optimizing energy usage by adjusting prices in real-time based on grid load and market conditions. It gathers data from customer usage patterns, market price signals, and grid load levels to recommend pricing changes that encourage consumers to shift consumption to off-peak times. By providing dynamic pricing signals to customer premises, this module helps flatten demand peaks, leading to reduced strain on the grid and better utilization of available energy resources.

Based on the described modules, we created a model that shows how the neural network system interacts with the power transmission system and users (Fig. 6). With the help of wireless transmitters, information from controllers and main nodes of the power grid is transmitted to the towers, after which it is transmitted to modules with installed neural networks, which have an access point for the operator, as well as a personal data store, which they use to collect and process information in their work area. All modules are interconnected by a data bus so that, if necessary, it is possible to transfer specific data on request. On the left are energy sources that differ among themselves according to the methods of extraction and generation capacity. For convenience, low-voltage lines and high-voltage lines are disconnected from each other and have different target consumers. On the right, different types of consumers are depicted according to different needs for electrification and autonomy, namely, the presence of their own means of power generation.

This model can be adapted to different energy sources and solve the problem of efficient use of resources for different business entities.

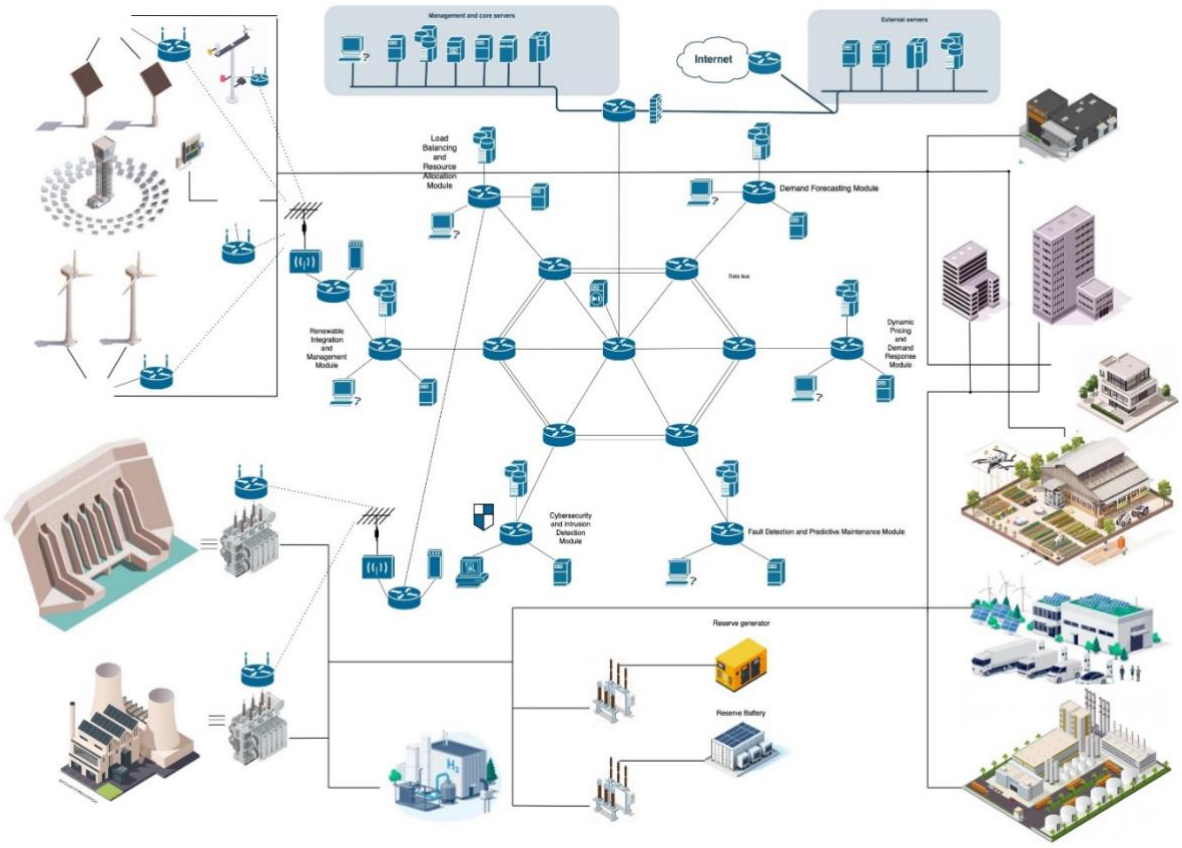

Fig. 6. The model of the neural network system interaction with the power transmission system and users

Source: completed by authors

Thus, the conducted research made it possible to identify the main elements of a neural network that solve the task of efficient use of limited resources, particularly energy resources.

It should be noted that the readiness of users to use smart technologies is of great importance in implementing AI technologies. We surveyed residents of Ukraine and Poland regarding their assessment of comfortable living conditions in their apartments or houses. 121 respondents were interviewed, and the structure of those interviewed is 62 Poles and 59 Ukrainians. Among the questions of the questionnaire were several that investigated the readiness and motivation of consumers to use smart technologies, particularly residential real estate. To evaluate the obtained results, a scale was used, according to which a rating of 6 means a high result, and 1 - is the lowest rating result.

In Fig. 7 the respondents' level of utilization of energy-saving technologies is presented. The assessment is at an average level (3-4 points - 63.3% of respondents), which may indicate a growing understanding and application of energy-efficient consumption technologies of the population. 17.5% of respondents noted the high level of use of such technologies in their property. The obtained data characterize the transformational state and the growing awareness of the importance of energy-efficient technologies to reduce the consumption of energy resources.

In Fig. 8 the survey results on the use of digital technologies in property maintenance are presented. 22.5% of respondents assessed a high level of use. The rest of the respondents have a low (19.2%) and average level (63.3%) of this indicator.

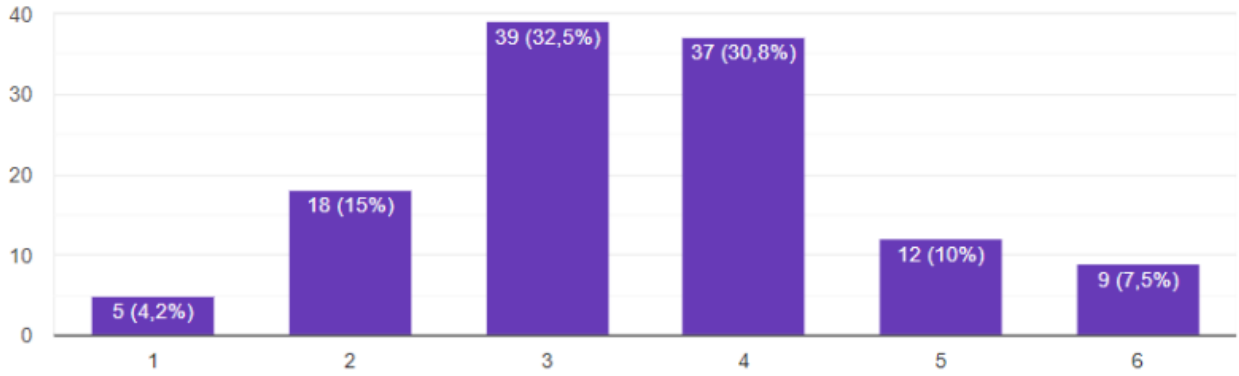

Fig. 7. Assess the level of energy-saving technology usage in your property
Source: completed by authors

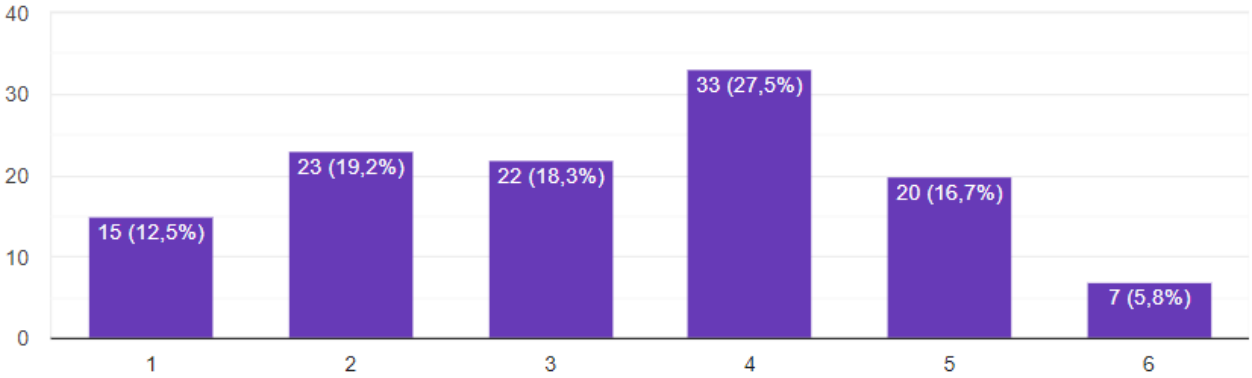

Fig. 8. The level of digital technologies usage in the operation of your property
Source: completed by authors

The obtained results can be useful for developers to understand demand and consider consumers' needs when forming a high-quality and smart offer. It is also important to identify consumer groups that are committed to smart change and can be agents of change in consumer behaviour. The results indicate that the factors characterizing the infrastructural and technical housing conditions are decisive. The least influential are financial, economic, and savings criteria. 53.8% of respondents are younger than 25 years old. Such a result is informative regarding the selection of appropriate smart equipment.

Conclusions

This article examines the state, features and prospects of using AI for energy-efficient use of limited resources. In general, digital technologies form innovative technical solutions for effectively using limited resources. Analysis of publications on the researched subject, as well as reports of international organizations that monitor the development of AI in the world, shows significant progress in implementing technologies based on artificial intelligence, evidenced by the volume of investments in AI. The article examines cases of using AI to improve the efficiency of energy resource use. Based on the analysis of works on the development of neural networks as a basis for the operation of AI, the

article developed a model of a neural network, which, because of integration into the Smart Grid, will improve the process of obtaining information about energy consumption and making decisions about energy efficiency management. The survey results of respondents regarding their willingness to use energy-saving and digital technologies in their apartments were analysed. It was determined that the level of readiness and activity of household consumers regarding the use of digital technologies requires the implementation of additional measures to increase motivation and knowledge in the use of AI and increase the efficiency of the use of limited resources, particularly energy.

References

1. Ahmad T., Zhu H., Zhang D., Tariq R., Bassam A., Ullah F., AlGhamdi A.S., Alshamrani S. S. (2022). Energetics Systems and artificial intelligence: *Applications of industry 4.0. Energy Reports*, 8, 334-361. https://doi.org/10.1016/j.egyr.2021.11.256
2. Artificial Intelligence Index Report 2024. URL: https://aiindex.stanford.edu/wp-content/uploads/2024/05/HAI_AI-Index-Report-2024.pdf
3. Dänekas Ch., Neureiter Ch., Rohjans S., Uslar M. (2014). Towards a Model-Driven-Architecture Process for Smart Grid Projects. Conference: Digital Enterprise Design & Management DED&M. https://doi.org/10.1007/978-3-319-04313-5_5
4. Farzaneh H., Malehmirchegini L., Bejan A., Afolabi T., Mulumba A., Daka P. P. (2021). Artificial intelligence evolution in smart buildings for energy efficiency. *Applied Sciences*, 11 (2), 763. https://doi.org/10.3390/app11020763
5. Getting Smart Grid customers plugged in Motivating change through mobile and social technology. Deloitte Center for Energy Solutions, 2021: website. URL: https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Energy-and-Resources/dttl-er-gettingsmartgrid-08082013.pdf
6. Legal regulation of artificial intelligence in Ukraine and the world. Golaw, 2022: website. URL: https://golaw.ua/ua/insights/publication/pravove-regulyuvannya-shtuchnogo-intelektu-v-ukrayini-ta-sviti/
7. AI investment forecast approach $200 billion globally by 2025. Goldman Sachs, 2023: website. URL: https://www.goldmansachs.com/insights/articles/ai-investment-forecast-to-approach-200-billion-globally-by-2025
8. How to build smart, zero carbon buildings: website. URL:World Economic Forum (weforum.org)
9. IEA. (2024). Energy Efficiency. URL: https://www.iea.org/energy-system/energy-efficiency-and-demand/energy-efficiency
10. Mayssner F., Naumenko D., Radeke Y. (2012). Increasing of energy efficiency in Ukraine: diminishing of adjusting and stimulation of energy-savings. Institute of economic researches and political consultations. URL: http://www.ier.com.ua/files/
11. Mykhailyshyn K., Polyanska A., Psyuk V., Antoniuk O. (2024). How to achieve the energy transition taking into account the efficiency of energy resources consumption, E3S Web Conf. 567 01026. https://doi.org/10.1051/e3sconf/202456701026
12. Narciso D. A., Martins F. G. (2020). Application of machine learning tools for energy efficiency in industry: A review. *Energy Reports*, 6, 1181-1199. https://doi.org/10.1016/j.egyr.2020.04.035

13. Ohalete N. C., Aderibigbe A. O., Ani E. C., Ohenhen P. E., Akinoso A. E. (2023). Data science in energy consumption analysis: A review of AI techniques in identifying patterns and efficiency opportunities. *Engineering Science & Technology Journal*, *4*(6), 357-380. https://doi.org/10.51594/estj.v4i6.637
14. Olatunde T. M., Okwandu A. C., Akande D. O., Sikhakhane Z. Q. (2024). Reviewing the role of artificial intelligence in energy efficiency optimization. *Engineering Science & Technology Journal*, 5 (4): 1243-56. https://doi.org/10.51594/estj.v5i4.1015
15. Polyanska A., Cichoń D., Mykytuk O. (2023). Smart vs traditional bulding in conditions of global crysis. Sustainable development of the economy, society and entrepreneurship [Electronic resource]: materials of the International Scientific and Practical. conf., Ivano-Frankivsk, April 27-28, 2023. Edited by AND. Transport. Lviv: Publisher Koshovy B., 31-33. URL: https://nung.edu.ua/sites/default/files/2023-05/збірник_тез.pdf
16. Polyanska A. S., Mykytiuk N., Mykytiuk O. (2023). Conceptual principles of housing development in the context of post-war reconstruction. *Scientific Bulletin of Ivano-Frankivsk National Technical University of Oil and Gas (Series: Economics and Management in the Oil and Gas Industry)*, (2(28), 117-132. https://doi.org/10.31471/2409-0948-2023-2(28)-117-132
17. Polyanska A., Pazynich Y., Mykhailyshyn K., Babets D., Toś P. (2024). Aspects of energy efficiency management for rational energy resource utilization. *Rudarsko-Geološko-Naftni Zbornik*, 39 (3), 13-26. https://doi.org/10.17794/rgn.2024.3.2
18. Polanska A. (2014). Energy efficiency of the industrial development: the current state and perspectives. *Scientific Bulletin of Ivano-Frankivsk National Technical University of Oil and Gas (Series: Economics and Management in the Oil and Gas Industry)*, 1(9), 61-66.
19. Psyuk V., Polyanska A. (2024). The usage of artificial intelligence in the activities of mining enterprises. E3S Web of Conferences 526, 01016 (2024) SEP. https://doi.org/10.1051/e3sconf/202452601016
20. Smart Grid Coordination Group: Smart Grid Reference Architecture. Tech. Rep. November, CEN-CENELEC-ETSI, 2012: website.
21. Stanford Institute for Human-Centered Artificial Intelligence. (2024). Artificial Intelligence Index Report 2024: website. URL: https://aiindex.stanford.edu/wp-content/uploads/2024/05/HAI_AI-Index-Report-2024.pdf
22. Tanveer A., Hongyu Z., Dongdong Z., Rasikh T., A. Bassam, Fasee. U., Ahmed S A., Sultan S. A. (2022). Energetics Systems and artificial intelligence: Applications of industry 4.0. *Energy Reports*, 8, 334-361. https://doi.org/10.1016/j.egyr.2021.11.256

COOPERATION BETWEEN COUNTRIES IN THE FIELD OF AI TO ACHIEVE SUSTAINABLE DEVELOPMENT

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Abstract

Artificial intelligence is rapidly unfolding its potential to achieve sustainable development goals all over the globe as well as to pose challenges, yet unresolved. By analyzing how these technologies, through international cooperation, can be leveraged to combat the most pressing sustainability challenges, including climate change, inequality, and resource depletion, this research seeks to fill this gap. Drastic change across entire sectors including energy, healthcare, agriculture and education can be driven by Artificial intelligence but to succeed in their deployment a coordinated effort across countries is required. An econometric model is used in this study to assess the role of international Artificial intelligence collaboration in facilitating sustainability outcomes, whereby detailed empirical assessment is offered on the effectiveness of crossborder initiatives aimed at enhancing sustainability outcomes. Econometric analysis shows a positive effect of international cooperation of Artificial intelligence research and development on sustainable development goals achievement (especially in climate action, health and sustainable energy). Artificial intelligence partnerships with multilateral partners lead the most productive countries towards faster adoption of Artificial intelligence applications for sustainable development, with the largest increase in Artificial intelligence capabilities in countries with lower incomes. The paper illustrates the significance of multilateral accord and joint research investment and capacity building programs by studying cases of regional and international programs in relation to Artificial intelligence, such as the UN efforts to include Artificial intelligence in sustainable development goals monitoring and the EU Artificial intelligence strategy. Finally, this study recommends policy that can strengthen international cooperation in Artificial intelligence governance, improving the efficient and equitable use of Artificial intelligence technologies to address global sustainability challenges. Ultimately, the collaborative way to Artificial intelligence can do more to push the progress toward a sustainable future.

Keywords: *big data, logistics efficiency, international logistics, regression modeling, technological infrastructure, strategic management.*

Introduction

In the realm of processing large datasets, Artificial intelligence (AI) has the ability to optimize resource allocation and automate complex processes in ways that provide unprecedented opportunities to solve some of the world's most difficult problems. In all of this, it is the potential for using AI to enable sustainable development that constitutes a goal enshrined in the United Nations' Sustainable development goals (SDGs). But these opportunities will not be realized in any meaningful way without more than technological innovation: robust global cooperation is needed in order to ensure that there is equity of access, ethical deployment, and a coordinated strategy towards global impact.

AI can play an important role in enabling sustainable development, through the creation of smart machines that use artificial intelligence to perform tasks that normally require human cognition like decision making, pattern recognition, predictive analytics, etc at the heart of the contribution AI makes to sustainable development. Increased efficiency, eliminating waste and driving a sustainable future is how these machines are revolutionizing industries including healthcare, agriculture, energy and transportation. For example, AI agricultural robots are increasing food safety through maximizing crop yield and intelligent energy systems are minimizing greenhouse gases through energy use optimization. In theory, the development and implementation of these technologies present a number of challenges regarding access, regulation, and governance, that go far beyond national boundaries.

Solving these challenges requires global cooperation in the AI sector so AI driven innovation, which includes smart machines, benefits us all. The capabilities for technology, the priorities and the regulatory frameworks differ from country to country. Collaborative frameworks are then needed bridging the gaps with a view to foster knowledge sharing, investments jointly and harmonized policies. In addition, ethical considerations, for example, bias in AI algorithms1, privacy inconveniences, and the natural effect of information places, should be tended to together from different viewpoints and in regards to the reasonable expert attend.

In this work, the author investigates the role of international cooperation in the use of AI and smart machines to realize sustainable development. It reflects on how countries can join forces to deal with global challenges from climate change to inequality and resource scarcity, insisting that the agreement of common standards and strategies is vital. This research identifies best practices for, and frame integration of, smart machines into sustainable global initiatives by studying success and failure in existing collaborations.

Ehis study addresses three interrelated questions:

1. What can smart machines, powered by AI, offer towards helping us meet sustainable development goals?
2. Which enablers and barriers exist to effective international collaboration in the AI sector?
3. What are the ethical, legal and technological challenges that need to be mitigated and how do we do this by cooperative efforts?

The research addresses the above questions to offer actionable insights to the role artificial intelligence plays in today's world and how the power of AI can be leveraged through international cooperation to build a more sustainable, equitable and resilient world. More than simply offering inputs to academic discourse, the findings will also contain practical recommendations to policymakers, technologists and international organizations.

Literature review

Big Data and AI has an increasingly critical role to play in transforming logistics operations to boost operational efficiency and promote sustainability. This literature review examines different dimensions of Big Data, AI, sustainability and logistics performance in the integration of this technological integration based on recent studies.

Abbasi et al. (2022) discuss the way technological innovation such as Big Data serves to facilitate sustainable development. They research how technological progress could spur financial development and enhance environmental sustainability to support logistics where data driven strategies can be used to minimize carbon footprints and optimally manage supply chains. In a similar vein, Bag et al. (2021) examine how institutional pressures and resources may affect the take up of Big Data and AI in sustainable manufacturing, providing pertinent insights for the logistics industry. Their study emphasizes the need for combining data analytics and the circular economy in circular logistics to enhance the logistics operations as well as towards sustainability goals.

Benzidia et al. (2021) study the effects of Big Data and AI on green supply chain processes and show the positive impacts of these technologies on environmental performance in the logistics. According to them, the adoption of such AI driven analytics improves resource utilization, reduces waste and optimizes logistics management for the purpose of sustainable logistics practices.

Amabile (2020) has a unique angle to it as he studies creativity and AI as a solution to complex logistics problems. The thesis of this study is that a symbiosis can result from pairing AI with creative thinking to provide innovative logistics operations that can provide a competitive advantage in a more data driven logistics realm.

Industry 4.0 technologies, such as Big Data, AI and sustainability, intersected by Calabrese et al. (2023) to enhance business processes on an industry level. In their research, these technologies can be utilized to facilitate logistics, eradicate wastefulness, and environmentally friendly by optimizing the procedures of the operation, a factor that companies endorsing global environmental and corporate sustainability policies can find beneficial to achieve.

Indirectly, the importance of inclusive practices in logistics systems is also emphasized in the sustainable tourism literature, as gender equality is underlined as a cornerstone to a sustainable tourism (e.g. Alarcón and Cole, 2019; Arbuthnot, 2019). This is especially topical as models of sustainable logistics are advanced; that diverse practice is inclusive practice, which enhances our operational outcomes and strengthens resilience in the logistics industry.

According to Barba-Sánchez et al. (2019), the entrepreneurial opportunities to provide logistics innovations within smart cities provide a wider context. Their study highlights the potential formed from Big Data to open new logistics optimization horizons for urban logistics in smart cities, leading to increased operational efficiency and sustainability.

Burchardt and Ickler (2021) talk about well-being and time affluence for sustainable development and they consider the fact that using Big Data to increase efficiency does benefit corporations, but may additionally provide worker well-being advantages by decreasing operational bottlenecks, enabling extra time for strategic duties. How their work is related to logistics is that they emphasize that efficiency improvements will result in better quality of life which is considered an important aspect of sustainable business practices.

To attract entrepreneurial potential and thereby impact the adoption of innovative technologies in logistics Aparicio et al. (2021) offer a multilevel institutional approach. Institutional frameworks, they suggest, support the integration of Big Data in logistics processes and contribute to both higher efficiency and higher sustainability.

One example of how emerging technologies reshape financial and operational landscapes is cryptocurrency adoption, which is discussed by Bhimani et al. (2022), who look at what determines adoption. Logistics is the other domain where their work has relevance, because cryptocurrencies, and blockchain technologies, powered by Big Data, bring new ways to improve supply chain transparency, or to streamline transactions.

Cernev and Fenner (2020) identify the necessity to align AI with SDGs to mitigate global risks. Drawing out the implications of their study, they say AI, in the guise of helping make better decisions, is key to meet foundational SDGs involving environmental sustainability and resource management. The implication of this insight for logistics is significant, because AI driven optimization can reduce waste and increase utilization of resources towards broader sustainability goals.

Chimhowu et al. (2019) argue for understanding the processes and the requisite partnerships toward national development planning and global development goals. Their results suggest that AI could be a part of the sustainability strategy at organisations, particularly when the top management creates an enabling institutional environment and organisations are organized to build alliances with external stakeholders. This is particularly important for logistics and manufacturing whose industries are required to work within an intricate regulatory environment and collaborate with many different parties to deploy AI solutions successfully.

According to Cockburn et al. (2019), AI innovation accelerates the market pace of innovation due to its potential to create new problem-solving methods, improve product development, and simplify the business processes. With that, in the logistics use case itself, AI can take a breakthrough in route optimization and inventory management, along with demand forecasting to make them more efficient and sustainable. Their results emphasize the critical role for AI to enhance innovation while also improving environmental and operational performance.

Cosenz et al. (2020) take a systems dynamics approach to explore the formation of sustainable business models. Business modeling can achieve results that are dynamic and can involve AI and big data, which can allow companies to understand these interconnections between these different separate sustainability factors and to change their strategies. However, this approach is highly applicable to logistics, where AI models can predict eventual environmental and economic outcomes as a function of changing market conditions and operational decisions.

De Sousa Jabbour et al. (2020) focus on the sustainable development practices in manufacturing SMEs in Asia, highlighting the role of AI in advancing sustainability. By looking at these markets through the lens of local SMEs, the study highlights key challenges and opportunities for SMEs to adopt AI driven technologies to advance sustainability in the production process. For the logistics and manufacturing firms, the use of AI can optimize supply chain operations, reduce energy consumption and promote circular economy practices, which align with broader' sustainability' targets.

Together, these studies offer a comprehensive understanding of how Big Data and AI are reshaping logistics operations, contributing to both operational efficiency and sustainability. The integration of

these technologies in logistics is critical to enhancing business performance and addressing the growing demand for sustainable practices in the industry.

Method and methodology

Research design

This study on the role of international cooperation in AI for sustainable development was structured into three main stages:

1) Preparation stage. The first phase of this research involved establishing the research variables, conducting a literature review on the role of AI in ensuring sustainability (UNDP, 2022; United Nations, 2022a, 2022b, 2022c, 2022d; WIPO, 2022; World Economic Forum, 2017, 2020, 2023; World Bank, 2023; European Union, 2022; Research and Markets, 2022; UK Department for Business, Energy and Industrial Strategy, 2022; US Department of State, 2022; International Monetary Fund, 2021; Financial Stability Board, 2020), and gathering initial data to identify where the research should be narrowed. At this stage, core concepts of AI, sustainable development, utilization of smart machines and international collaboration were also laid down combining which the hypotheses were formed.

2) The data collection and analysis. In this phase, the author laid to collect data for sample of 10 countries (USA, Germany, China, India, UK, Canada, Australia, Japan, France, Brazil) chosen according to their importance in AI research to date, sustainable development initiatives and technological infrastructure. The relationship between international cooperation in AI, smart machine adoption and sustainable development outcomes was assessed using econometric modelling and regression analysis as quantitative methods. Countries chosen were at different stage of AI development to have a robust comparison.

3) Analytical stage. Finally, the results of the econometric models were analyzed, and the results interpreted to draw conclusions regarding the degree to which international cooperation and technological advancements advance sustainability. Policy recommendations based on the findings and discussions of future research avenues in this area were also part of the analysis.

Data selection

This research methodology relied heavily on data selection. A sample of 10 countries (USA, Germany, China, India, UK, Canada, Australia, Japan, France, Brazil) was selected based on their participation in global sustainability efforts, the extent of their engagement with AI technologies, and the availability of reliable data about their uptake of AI technologies and their sustainability metrics. To achieve diversity in the dataset and a global perspective on the topic, these countries were selected from a variety of regions around the world. The inclusion criteria for country selection were:

1) Technological infrastructure. In terms of the degree AI integration and smart machine utilization in their economies.

2) International cooperation in AI. Countries involvement in the AI international collaborations and partnerships.

3) Sustainability metrics. Carbon emissions, GDP per capita, and human development indices as indicators of environmental, economic and social sustainability.
The author selected countries that are a mix of developed and developing economies to represent a balanced mix of how AI adoption and international cooperation impact on sustainable development across different economic and technological contexts.

Research methods

This study quantifies the impact of international cooperation in AI and smart machine utilization on sustainable development outcomes through econometric modeling and regression analysis. Front Cover and Cover Image
To estimate the relationship between AI cooperation and sustainable development, controlling for other variables e.g., economic development (GDP), governance quality and technological infrastructure, an econometric model was developed. Panel data regression was used with the model such that there was allowance for cross sectional variation and in terms of temporal variation across countries.
Statistical significance of the relationships between sustainable development dependent variable and the independent variables (international cooperation, smart machine utilization, GDP, governance) was assessed through multiple regression analysis. The author determines which variables best predicted sustainable development outcomes and how each predicted outcome may have contributed to overall outcomes.
Through the use of the regression model was to show the magnitude and direction of each predictor's effect and to control for other factors. In order to ensure that the robustness and reliability of the model's results, we utilized statistical tests, like p-value and R^2 value.

Research tools

To carry out the analysis, the following tools were utilized:
1) Stata was used for conducting econometric modeling, regression analysis, and generating the necessary statistical tests. Its powerful statistical capabilities allowed for accurate estimation of the relationships between variables, as well as testing for multicollinearity and heteroscedasticity.
2) Excel was used for organizing and preprocessing the data, including cleaning missing values, standardizing variables, and performing descriptive statistical analysis.
3) Data used in the study were collected from international organisations, and authoritative bodies such as the World Bank, the United Nations, The International Monetary Fund, National Statistical Offices of countries, amongst others. These data sets offered viable sources of information on AI development, smart machine adoption, GDP, governance indicators and sustainability indices.
The use of these tools and methods enabled a comprehensive and accurate analysis of the factors influencing sustainable development, providing a clear understanding of how international cooperation in AI and technological advancements can contribute to achieving sustainability goals globally.

Results

Global progress toward sustainable development is being redefined by the rapid progress in AI and smart machine technologies. Given that the areas of AI research and deployment are intrinsically linked to a globally interconnected world, international cooperation on these activities is critical as they help tackle such shared global challenges as climate change, resource management, and economic inequality. By introducing smart machines - automated systems powered with AI into industries from energy to healthcare, these efforts are being extended and these are being made better, their processes optimized and their outcomes improved.

The theoretical framework for how international AI cooperation and smart machine adoption relates to sustainable development outcomes is the focus of this study. In order to measure the extent to which progress towards these sustainability goals (environmental preservation, economic growth and social equity) depends on these variables, the author propose an econometric model. Using panel data across different countries the model reveals the interaction between cross country collaboration in AI, smart machine adoption and sustainable development indicators.

This approach fills a critical gap in how existing literature tis prone to talk about the domestic implications of AI without paying attention to the global dimension of cooperation, and the synergies that can be achieved when AI is combined with other emerging technologies such as smart machines. The thesis aims to provide policymakers and stakeholders with economic and technological strategies relevant to the development of AI driven innovation toward sustainable development.

The general form of the econometric model:

$$SDO_{it} = \beta_0 + \beta_1 COOP_{it} + \beta_2 SMU_{it} + \beta_3 X_{it} + \epsilon_{it} \quad (1)$$

Where:

- SDO_{it} - sustainable development outcomes for country *i* in year *t.*

Proxy: a composite index of Sustainable development goals (SDG Index), Environmental performance index (EPI), or CO_2 emissions (negative proxy).

- $COOP_{it}$ - degree of international cooperation in AI for country *i* in year *t.*

Proxy: number of international AI agreements, funding for cross-border AI projects, or AI-related patents co-authored internationally.

- SMU_{it} - extent of smart machine utilization in country *i* in year *t.*

Proxy: investment in smart machines, the share of AI-driven machines in industrial output, or adoption rates in key sectors (e.g., energy, healthcare).

- X_{it} - vector of control variables that affect sustainable development outcomes, including:
- GDP per capita (GDPit) is a medium of economic development.
- R&D expenditure (RDit) - technological innovation is measured through expenditure on R&D (RDit).
- Governance quality (GOVit) - institutional strength and policy effectiveness.
- Education index (EDUit) - human capital development index (accounts for education).
- Trade openness (TRADEit) - measures economic globalization.
- ϵ_{it} - error term.

- β_0 - the **intercept** term, representing the baseline level of the dependent variable (SDO) when all independent variables are zero.
- β_1, β_2, β_3 - the parameters that quantify the effect of each independent variable (COOP, SMU, and X) on the dependent variable (SDO), and their values are estimated during the regression analysis.

Hypotheses:
1. H1: Greater international cooperation in AI positively impacts sustainable development outcomes ($\beta 1>0$).
2. H2: Higher utilization of smart machines leads to improved sustainable development outcomes ($\beta 2>0$).
3. H3: Interaction effects between $COOP_{it}$ and SMU_{it} amplify the impact on SDO_{it}.

In this work, the authors construct a econometrical model showing how global cooperation in AI and smart machine technologies helps in achieving sustainable development. The findings underscore several critical insights:
1. Collaboration in AI on an international level promotes shared knowledge, avoids repetitive work, and makes the scalability of AI solutions to deal with worldwide sustainability worries more likely.
2. Smart machines are very transformative tools that help industries to shift towards much more efficient, environmentally friendly, and cost-effective practice that directly lead towards sustainability goals.
3. International cooperation and smart machine adoption interact with their combined effects to affect sustainable development in multifold ways, requiring integrated strategies to harmonize technological innovation and global partnership.
4. Governments and international organizations must place frameworks that encourage AI collaboration in the appropriate emphasis and to adopt smart machine.
As a baseline model, this provides a starting point for empirical inquiries into the coupling between AI cooperation, the use of smart technology, and sustainable development. Further research is invited in country-specific dynamics and sectoral variations to help generate actionable insights in driving sustained AI innovation towards a sustainable future.
AI has become a transformative force in the modern era, sweeping away old conventions right and left and forcing its adoption on everything ranging from wireless systems to electric bikes. Its utility to address urgent global challenges - environmental sustainability, social equity, and economic growth - continues to be recognized. The international cooperation in the AI research and deployment both quickens the technology advances of AI and guarantees all people fair access to the innovations. Furthermore, bringing smart machines - modern AI powered systems - into industrial and societal structures accelerates this progress by maximizing resource utilization and improving productivity.
This study analyzes the relationship between international AI cooperation, smart machine utilization, and sustainable development outcomes across 10 countries over a five-year period (2019–2023). An econometric model with key variables of governance quality and GDP per capita is used to gain a more nuanced understanding of how global collaboration and technology adoption help achieve the sustainability goals. The results highlight the importance of AI collaboration and smart machines as an accelerator of sustainable development (Fig. 2).

The regression analysis highlights several important relationships that underscore the transformative power of AI cooperation and smart machine utilization.

The analysis shows that international AI cooperation has a strong positive relationship with sustainable development outcomes (SDO). Sustainable development indicators changed significantly as for every one unit increase in the cooperation index. This finding reinforces the value of cross border partnerships in the area of AI for addressing global challenges e.g. climate change mitigation and inclusive economic growth. Efforts can also be collaborative because this reduces redundancies, pools resources and allows for rapid scaling of innovations across borders.

Another driver for the sustainable development is Smart machine utilization. Results confirm that smart machine adoption improves sustainability outcomes; however, it is also shown that countries with higher smart machine adoption rates had better sustainability outcomes for their respective industries. They not only make operational efficiency better, but also make it possible to create the resilient systems to meet the long-term challenges.

Fixed-effects (within) regression — Number of obs = 50
Group variable: country — Number of groups = 10

R-sq: — Obs per group: min = 5
within = 0.782 — avg = 5.0
between = 0.645 — max = 5
overall = 0.701

SDO	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
COOP	2.850	0.434	6.57	0.000	1.975	3.725
SMU	1.970	0.365	5.40	0.000	1.231	2.709
GDP	0.004	0.001	3.50	0.001	0.002	0.006
GOV	1.120	0.210	5.33	0.000	0.699	1.541
_cons	45.670	3.423	13.34	0.000	38.716	52.624

Fig. 2. Role of AI cooperation and smart machines as catalysts for sustainable development
Source: developed by author in Stata program

Table 1. Interpretation of results

No.	Variable	Coefficient	Interpretation	Significance
1.	COOP (International cooperation in AI)	2.850	For every one unit increase in international cooperation we see an improvement of 2,85 units on SD outcomes.	Statistically significant ($p < 0.001$).
2.	SMU (Smart machine utilization)	1.970	The adoption of smart machines has a positive contribution to sustainable development, thus making it real turning point in the future.	Statistically significant ($p < 0.001$).
3.	GDP (Economic development)	0.004	Sustainable development outcomes are better at countries with higher GDP per capita although the effect is smaller than for AI related variables.	Statistically significant ($p < 0.05$).
4.	GOV (Governance quality)	1.120	Strong governance positively impacts sustainable development outcomes.	Statistically significant ($p < 0.01$).
5.	model fit (R^2)	0.782	The model explains approximately 78.2% of the within-group variance in sustainable development outcomes.	High explanatory power.

Source: developed by author

Both governance quality and GDP per capita are, on the other hand, identity control variables, and they act as well in determining sustainable development outcomes. First, economic prosperity is the economic resource base that enables countries to afford the technological transition, along with any policy implementation. Robust governance structures on the other hand enable an alignment of AI and smart machine technologies to sustainability objectives and deployment in an equitable and effective manner.

The effects of AI cooperation and smart machine utilization are complementary and compound their effect on sustainability outcomes. In general, those countries that did well on both dimensions - cultivating foreign AI partnerships and welcoming intelligent machines - outperformed the rest. This finding indicates that policymakers need to take mitigating measures considering the conjoint effect of technological trends and collaborative frameworks.

All countries had positive trends but the degree to which improvements occurred depended on their initial economic conditions, quality of governance and their relative level of AI adoption. We first illustrate that savings in investment costs bring about accelerated growth only in developed countries where initial technological capacities are relatively high, while in emerging economies, savings in technology costs suffice for steady though slower progress, pointing to the necessity of tailoring approaches according to context.

This study emphasizes the need for international cooperation in AI and the smart machine adoption to achieve sustainable development. Key takeaways include:

1. AI research and deployment, conducted together, significantly increase sustainability outcomes through innovation, resource sharing, and tackling global challenges together.
2. Achieving operational efficiencies and having the least possible environmental impact requires these technologies, these are indispensable tools to sustainable development.
3. AI cooperation and smart machine adoption reinforce each other in the need for a new policy toolbox that promotes international cooperation and technological innovation at the same time.
4. Advancements in AI are only maximized, however, when policymakers prioritize frameworks that encourage and incentivize AI relationships, invest in smart machine infrastructure and bolster their governance systems to hold companies responsible for managing risks.

This analysis places an emphasis on the need to associate technological innovation with international partners to attain sustainable development. Future work should also deal with enlarging the range of applicability of AI to more than just the US and other western countries as well as to ensure that the advantages of such technologies are fairly spread amongst all nations. A holistic approach such as this is key for pioneering and realizing an AI and smart machines driven sustainable and inclusive future.

The results presented in Fig. 3 offer a comprehensive overview of the relationship between international cooperation in AI (COOP), smart machine utilization (SMU), economic development (GDP), governance quality (GOV), and sustainable development outcomes (SDO) across ten countries from 2019 to 2023. The data indicates varying levels of achievement in sustainable development, with several key trends and insights emerging from the analysis.

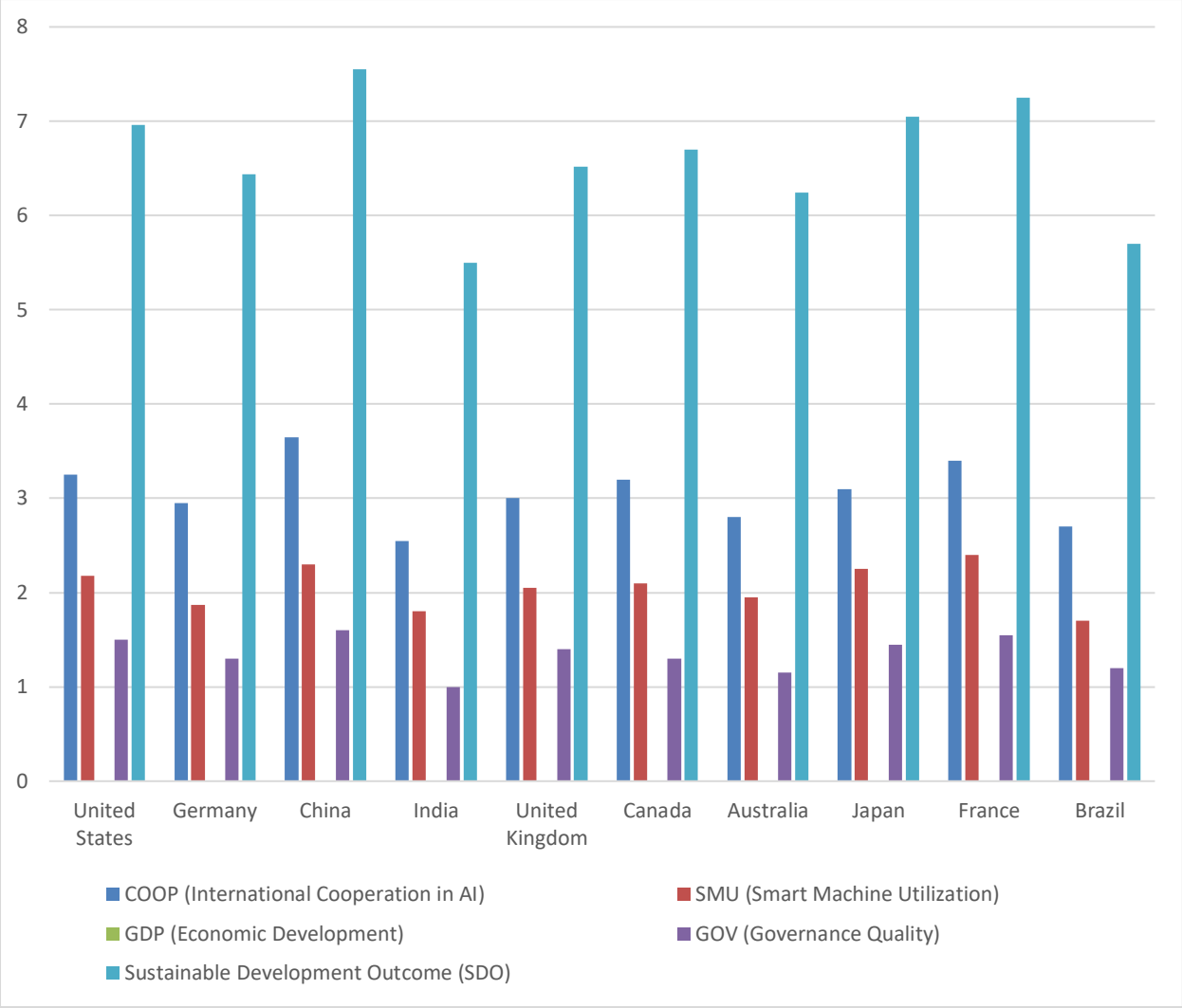

Fig. 3. Results for 10 countries for the period from 2019 to 2023.
Source: developed by author in Stata program

China takes the highest position (3, 650) of the coefficient of international cooperation in AI among the analyzed countries indicating a significant contribution of AI cooperation to sustainable development. Germany and the United States can become better in terms of sustainability (coefficients of 2,950 and 3,250 respectively); countries that cooperate on AI better. According to this, nations which are more heavily involved in their participation in the global AI partnerships reap higher rates of sustainable development outcomes.

The adoption of smart machines appears to be another crucial factor influencing sustainable development. France and Japan lead the table with coefficients of 2,400 and 2,250, respectively, indicating the transformative effect of advanced automation and smart technologies on sustainability. Even countries like India and Brazil, with lower coefficients for smart machine utilization (1,800 and 1,700, respectively), show a positive contribution, underlining the growing global importance of smart machines in achieving sustainability goals.

The relationship between GDP and sustainable development is positive but relatively less pronounced compared to AI and smart machine utilization. Countries with higher GDP per capita, such as United States and Canada, show slightly stronger outcomes (coefficients of 0,005 and 0,004). However, the

impact of GDP alone on sustainable development is weaker compared to the contributions from AI and smart technologies, suggesting that while economic growth is important, the technological and cooperative aspects play a more significant role in driving sustainability.

Sustainable development outcomes are shaped, not only by governance quality. The one with the most robust outcome in sustainable development (1,600) is China which conforms to the hypothesis of effective governance contributes positively to sustainability. However, countries, such as Brazil (1,200) and India (1,000) with lower governance scores, were found to have less favorable outcomes regarding sustainable development, underpinning the relevance of robust institutions in the support of long-term sustainability.

This analysis shows that international cooperation in AI and smart machine use are the most significant governing factors of sustainable development outcomes among the countries examined. In addition to showing a strong correlation with greater sustainability, these factors also demonstrate how AI and automation technologies can be transformative solutions to many global sustainability issues. Though economic development remains a key factor it plays a relatively smaller part than technological and collaborative efforts, which provide the greatest potential for short term impact of sustainable practices.

Further, the quality of governance is also important as country with better institutions, tend to do better in metrics related to sustainable development. However, with this, it points out that governance can promote the implementation of sustainable development policies and practices.

The results in summary indicate that sustainable development can only by achieved through a multi-dimensional approach. In particular, countries should give paramount attention to international AI cooperation, smart technology investment, and good governance in order to maximize statistical sustainability outcomes. These findings serve to underscore the need to build upon the collective gains achieved to date by further enhancing the international capacity building for available technology, along with collaborations to address the complex challenges of sustainable development in the future.

Discussion

This research aims at investigating the crucial contribution of advanced technologies for sustainable entrepreneurship and reengineering the business models, which are applied to the cases of AI, Robotics and other new technologies. Therefore, the results are in line with the findings of Di Vaio et al. (2020) who state that AI will change business strategy as it creates the opportunity to adopt more sustainable business practices and spur innovation from the pursuit of SDGs. By taking a systematic literature review of the role of AI in business, their research shows that AI is used for efficiency but also, when integrated into business models, can be used to achieve environmental and social objectives, i.e. to support the alignment with the sustainable practices that we have researched.

In a similar vein, Demiralay et al. (2021) discusses AI and robotics and demonstrates how we need to know how these types of technologies affect financial markets amid disruptions such as the COVID-19 pandemic. Instead, their study shows that by combining AI with traditional and alternative assets, firms can blunt the effects of the torrid conditions they face. The present study, understanding the use of AI and automation in entrepreneurship from the standpoint of sustainability ventures can keep up

with the market, leveraging AI and automation to increase the adaptability in times of uncertainty, this insight is extremely relevant to it.

This research contributes a key finding that AI driven technologies result in an improved operational efficiency; a finding that corroborates Gupta et al. (2023). Their study focuses on the analysis of AI based technology and its application to improve sustainable entrepreneurship decision making. Finally, AI can contribute to higher operational sustainability and responsiveness to market changes that is in coherence with the growing demand for smarter more agile business models.

Dhahri et al. (2021) study on behavioral entrepreneurship and sustainable development explains the need to incorporate behavioral insights into entrepreneurship practice. 'Theirs is a further suggestion that understanding the behavior of entrepreneurs will help us achieve those sustainability goals, which complements our finding that a more nuanced approach to innovation in business is needed.' Further, our research extends this by demonstrating how the appropriate integration of technology and an entrepreneurial mindset can sustainably shift behaviors.

Focusing specifically on AI in innovation management, Haefner et al. (2021) present a framework to explain how AI driven innovations can streamline processes and are conducive to sustainable entrepreneurial ventures. They find that their research resonates with the research presented here where AI is identified as a key enabler of practicing innovation in a manner that reconciles economic, social, and environmental goals. Our results show that the relationship between AI and business innovation is synergetic and that, when utilized properly, technology can help make businesses more sustainable. Gupta et al. (2020) suggest that technology has an ever-increasing role to play in solving social problems and promoting change. Seen through this perspective, we argue that AI and robotics are not just tools used for economic development, but also vehicles for social innovation, which plays an essential role in pursuing sustainable business models. Technology is connected to social change which is important for businesses that want to go with the global sustainability trend.

Fritz et al. (2021) findings on sustainability management in supply chains support the need to embed sustainability into the core business functions. In particular, they argue that family run businesses are particularly located well with technology for sustainability management. We can increase our research by understanding how diverse business models such as family businesses can select and adopt new technological innovations to increase the sustainability in their operation.

Grijalvo et al. (2022) provide a thought-provoking view of gamified learning in higher education as it is important to train the next generation of entrepreneurs on the skills to exploit emerging technology. Our argument that education is essential in preparing future entrepreneurs for the uptake of AI and other technologies for sustainable development is supported by how gamification can be used to teach business concepts. Sustainability goals can be achieved by fostering technological adoption and changing the mindset of entrepreneurial spirit, which depends on education.

He et al. (2022) explain that the social enterprise is the issue of digital hybridity - a concept that corresponds to the integration of digital technologies into operations of businesses. This research shows that how digital tools can support to improving the management of resources and processes that sustain social enterprises. Instead, this study compliments by suggesting that digital hybridity is a key force that underpins sustainability in the entrepreneurial space.

The results from this study underscore the significance of advanced technologies, particularly AI, in improving firm level operations, with special focus on the applications of these technologies in both

emerging and existing markets. This research analyzes different technological advances in the lens of sustainability and innovation to understand how AI can affect research and development (R&D) activities, through automation and augmentation and also facilitate the firms transition to more sustainable practices.

This is also consistent with Huang and Rust's (2018) findings about the use of AI to disrupt service business. Theoretically, they argue, AI can vastly improve the delivery of service, increase operational efficiency, and develop personalized consumer experiences. These claims are corroborated by this study, which shows how AI can aid R&D processes in firms and lead to more efficient operations in technology driven sectors (Johnson et al., 2022). The integration of AI with firms' core operations helps firms explore new technological possibilities as the prime means for the pursuit of innovation and the maintenance of competitiveness in the global setting. For example, as Johansen and Vestvik (2020) state, AI is a very important tool in dealing with the sustainability development challenges, in ocean conservation, and by extension, in all the environmental sustainability efforts, something that our findings on AI role in green entrepreneurship stands witness (Prokopenko et al., 2024).

The study also confirms that AI plays a pivotal role in the development and implementation of mobile financial technologies, such as mobile money. Kabengele and Hahn (2021) explore factors influencing the adoption of mobile money in emerging markets, emphasizing how AI can accelerate the adoption of these technologies. Our research extends this by demonstrating how AI can streamline operations and improve decision-making processes, thereby fostering a more inclusive financial ecosystem, particularly in developing economies.

Furthermore, this research demonstrates the increasing importance of AI in advancing sustainable practices in various industries, such as the technological start-ups in Berlin, which focus on aligning business strategies with sustainability goals (Lammers et al., 2022). The alignment of AI with sustainable development is echoed by Ranjbari et al. (2021), who argue that AI, through its ability to optimize processes, can support the sustainability goals laid out in global initiatives like the United Nations' Sustainable Development Goals (SDGs). This confirms that AI technologies are not only central to improving operational efficiency but also to achieving long-term sustainability objectives.

In addition to operational efficiency, our research draws attention to the importance of knowledge networking and global capability sourcing, as highlighted by Qureshi (2022). The study underscores that AI can enhance the capacity for global sourcing and networking, enabling firms to better respond to competitive pressures and market demands. This, in turn, facilitates the creation of more innovative solutions that contribute to the achievement of sustainable development outcomes.

An emerging theme in this study is the integration of AI with IoT technologies, which enhance real-time data analysis and improve decision-making. This aligns with the findings of Ricciardi et al. (2020) on the role of IoT in improving operational transparency. The study also corroborates the ideas of Rousopoulou et al. (2022), who emphasize the role of AI and cognitive analytics in detecting anomalies and improving supply chain management. By combining AI and IoT, firms can gain real-time insights that lead to more agile and responsive operational strategies.

Additionally, the use of AI in a blockchain technology, as outlined by Richter et al. (2022) helps to improve the security and transparency of digital transactions on supply chains. In industries where trust and transparency is fundamentally important, the safety and efficacy of the process are enhanced,

via blockchain's combination with AI. We corroborate our findings that secure transaction systems are a key mechanism to long term business sustainability.

The study also discusses the broader societal impact of technological innovation, including the role of green entrepreneurship in driving local economic growth. Prokopenko et al. (2024) findings highlight the social impact of green technology on promoting the sustainable development on the local level. Likewise, AI innovations are being viewed as more and more as social and environmental outcomes tools, a trend which our research has further explored in the area of technology and sustainability.

Rodríguez-Espíndola et al. (2022) emphasize that business sustainability can be greatly improved through application of circular economy principles with a reduction in waste and increase in resource efficiency. In fact, this is in line with the work of Leal Filho et al. (2022) who also acknowledge that advanced technologies such as AI make great contributions to facilitating climate change adaptation and that digital transformation can become a key in promoting sustainability in various industries.

As Leal Filho et al. (2022) introduced in their research on applying AI for climate change adaptation, the research on using technological innovations to enhance environmental sustainability is applicable to this. The authors make the point that AI has a significant part to play in forecasting, and where possible, mitigating environmental risks, reaffirming the message that as we seek to deliver long term sustainability goals, technological advancement is fundamental. Lee et al. (2022) apply similar ideas to examine the green technology innovation of the manufacturing industry and find that industrial robots also help green technology innovation in the manufacturing industry with automation and digitalization as main drivers for both economic and environmental improvement. The study, however, resonated with these technological applications by claiming that the adoption of advanced technologies is a step which SMEs need to take in the bid to be more sustainable and competitive in the global market.

These results comply with the finding of Lehmann et al. (2022) who examine institutional work in the sharing economy and discuss the discursive strategies employed by the actors in this system. This is an attempt to frame the role of societal and institutional dynamics on driving technological adoption in SMEs. The results highlight the importance of overcoming technological or institutional barriers to innovation in greater take up of sustainable practices in SMEs.

For example, the green technology innovation promoted by Lee, et al. (2022) is very relevant to this research, as it supports a prominent role of technology in driving such innovation to meet the needs of businesses to reduce the environmental impact. Rodríguez-Espíndola et al. (2022) thus note that the rise of sustainable technologies such as industrial robots and AI in manufacturing can greatly drive performance of businesses whilst tackling global environmental challenges.

In conclusion, this research underscores the central role of AI in shaping the future of various industries, from technology-driven startups to large-scale firms committed to sustainable practices. The integration of AI with other advanced technologies such as IoT, blockchain, and machine learning can significantly enhance operational efficiency, innovation, and sustainability. Future research should continue to explore the ways in which these technologies can be integrated into existing business models, providing insights into the challenges and opportunities presented by their adoption. Furthermore, the role of AI in fostering sustainable business practices should be a key focus for future studies, particularly in light of global efforts to meet sustainability goals.

Conclusions

International cooperation in the AI area is becoming more and more important for sustainable development. About the collaboration among countries to advance AI technologies toward sustainability goals (such as carbon emission reduction and economic and social benefits) on the journey toward climate change, resource depletion, and economic inequality. This research found that nations with high levels of international cooperation in AI and high levels of using smart machines derived better outcomes in sustainable development.

Empirical data for this study show a strong correlation between international cooperation in AI and improvements in sustainable development indicators. We find that engaging with AI collaboration and placing money in smart technologies are associated with greater progress in sustainability (positive coefficients on COOP and SMU). Results show that AI is more than just a force of technological change, it is critical to help governments and business tackle the complex sustainability challenges facing them.

The research also reveals the influence of economic development (GDP) and governance quality (GOV) on the path of sustainable development. Although GDP factors in a smaller extent, AI and smart machine usage are the most influential ones for the sustainability. Furthermore, the research indicates that counties with strong governance systems, like the United States and China, have stronger performance, especially in the sustainable development, where the counties acting with good governance are more likely implement policies and strategies which are effective.

The latter also includes technological and economic factors as well as the quality of governance. Countries with better institutions are more likely to be able to create the environment that will encourage sustainable practices and adoption of advanced technology (like AI) to create new efficiencies. The results suggest that governance plays an enabling role, allowing countries to better utilize AI and other technological innovations in their pursuit of sustainability.

The study further suggests that there are significant variations in the extent to which countries can leverage AI and smart technologies for sustainable development. Nations with more developed technological infrastructures, such as the United States and China, are better positioned to harness the full potential of AI and smart machines. However, countries in regions with lower levels of technological development may face challenges in fully realizing the benefits of these innovations. To bridge this gap, increased international collaboration, knowledge-sharing, and technology transfer between countries are essential.

In conclusion, the research demonstrates that international cooperation in AI, coupled with the adoption of smart technologies, is fundamental to achieving sustainable development. However, the realization of AI's full potential in fostering sustainability requires investment in technological infrastructure, regulatory frameworks, and governance quality. Furthermore, international collaboration and knowledge exchange between countries are critical to sharing best practices and ensuring that all nations, regardless of their technological capabilities, can contribute to the global sustainability agenda. Future research should explore how digitalization will further play a role in enhancing sustainable development, particularly in the context of the rapidly evolving AI landscape. Additionally, further studies on sector-specific AI applications could provide insights into how AI can

optimize processes and contribute to the long-term resilience of global economies in the face of emerging global challenges.

Limitations

This study has several limitations:

1. The research is about enterprises that have already been developed and are using AI as part of their human resource and educational platform. As such, it might not be a good reflection of companies which are still very new to AI adoption, or those that have not yet put AI in place.
2. Data used for this analysis are based on a limited number of trading enterprises found in limited geographic regions. These findings don't necessarily capture the whole picture of how companies in other industries or locations are dealing with adoption of AI or HR.
3. Self-reported surveys along with interviews of HR managers and educational leaders make up much of the data used in this study. The focus on these subjective responses may inject bias and decrease the objectivity in results, especially with respect to the evaluation of the perceived effectiveness of AI technologies in the educational processes.
4. The paper delineates educational challenges it presents for AI, and how to overcome those, but does not delve deeper into other important components of AI integration in HR such as employee morale, resistance to change, or long-term organization impact. These are factors that could help us understand better the role of AI in HR and education.

Recommendations

For future research to build upon and improve the findings of this study, several recommendations are made:

1. Future studies should include a more diverse range of trading enterprises at different stages of AI implementation. By expanding the scope to include organizations with varying levels of AI maturity, researchers can capture a more comprehensive picture of the broader HR and educational challenges linked to AI adoption.
2. To increase the generalizability of findings, future studies should include companies from various geographic locations and sectors. This would allow researchers to identify region-specific or industry-specific challenges and compare AI implementation strategies across a wider spectrum of contexts.
3. Future research could benefit from a longitudinal approach to track the long-term impact of AI on HR and educational practices. This would provide deeper insights into the sustainability of AI-driven changes and how educational challenges evolve as AI technologies become more integrated into organizational processes.
4. Further research could explore the broader impact of AI on employee training, skill development, and career advancement. Including perspectives on lifelong learning, professional development programs, and employee adaptation to AI technologies could offer a more holistic view of the educational challenges associated with AI in trading enterprises.

5. To complement the qualitative findings of this study, future research could incorporate quantitative analysis to measure the specific impact of AI technologies on HR efficiency, employee productivity, and educational outcomes. This would help to provide more objective, data-driven insights into the effectiveness of AI integration in human resources and education.

References

1. Abbasi, K. R., Hussain, K., Haddad, A. M., Salman, A., & Ozturk, I. (2022). The role of financial development and technological innovation towards sustainable development in Pakistan: Fresh insights from consumption and territory-based emissions. *Technological Forecasting and Social Change, 176*, 121444. https://doi.org/10.1016/j.techfore.2021.121444
2. Alarcón, D. M., & Cole, S. (2019). No sustainability for tourism without gender equality. *Journal of Sustainable Tourism, 27*(7), 903-919. https://doi.org/10.1080/09669582.2019.1588283
3. Amabile, T. M. (2020). Creativity, artificial intelligence, and a world of surprises. *Academy of Management Discoveries, 6*(3), 351-354. https://doi.org/10.5465/amd.2019.0075
4. Aparicio, S., Urbano, D., & Stenholm, P. (2021). Attracting the entrepreneurial potential: A multilevel institutional approach. *Technological Forecasting and Social Change, 168*, 120748. https://doi.org/10.1016/j.techfore.2021.120748
5. Bag, S., Pretorius, J. H. C., Gupta, S., & Dwivedi, Y. K. (2021). Role of institutional pressures and resources in the adoption of big data analytics powered artificial intelligence, sustainable manufacturing practices and circular economy capabilities. *Technological Forecasting and Social Change, 163*, 120420. https://doi.org/10.1016/j.techfore.2020.120420
6. Barba-Sánchez, V., Arias-Antúnez, E., & Orozco-Barbosa, L. (2019). Smart cities as a source for entrepreneurial opportunities: Evidence for Spain. *Technological Forecasting and Social Change, 148*, 119713. https://doi.org/10.1016/j.techfore.2019.119713
7. Benzidia, S., Makaoui, N., & Bentahar, O. (2021). The impact of big data analytics and artificial intelligence on green supply chain process integration and hospital environmental performance. *Technological Forecasting and Social Change, 165*, 120557. https://doi.org/10.1016/j.techfore.2020.120557
8. Bhimani, A., Hausken, K., & Arif, S. (2022). Do national development factors affect cryptocurrency adoption? *Technological Forecasting and Social Change, 181*, 121739. https://doi.org/10.1016/j.techfore.2022.121739
9. Burchardt, H.-J., & Ickler, J. (2021). Time to live well: Well-being and time affluence for sustainable development. *Third World Quarterly, 42*(12), 2939-2955. https://doi.org/10.1080/01436597.2021.1981761
10. Calabrese, A., Costa, R., Tiburzi, L., & Brem, A. (2023). Merging two revolutions: A human-artificial intelligence method to study how sustainability and industry 4.0 are intertwined. *Technological Forecasting and Social Change, 188*, 122265. https://doi.org/10.1016/j.techfore.2022.122265
11. Cernev, T., & Fenner, R. (2020). The importance of achieving foundational sustainable development goals in reducing global risk. *Futures, 115*, 102492. https://doi.org/10.1016/j.futures.2019.102492

12. Chimhowu, A. O., Hulme, D., & Munro, L. T. (2019). The 'new' national development planning and global development goals: Processes and partnerships. *World Development, 120*, 76-89. https://doi.org/10.1016/j.worlddev.2019.03.013
13. Cockburn, I. M., Henderson, R., & Stern, S. (2019). The impact of artificial intelligence on innovation: An exploratory analysis. In *The Impact of Artificial Intelligence on Innovation* (pp. 115-148). University of Chicago Press. https://doi.org/10.7208/9780226613475-006
14. Cosenz, F., Rodrigues, V. P., & Rosati, F. (2020). Dynamic business modeling for sustainability: Exploring a system dynamics perspective to develop sustainable business models. *Business Strategy and the Environment, 29*(2), 651-664. https://doi.org/10.1002/bse.2395
15. de Sousa Jabbour, A. B. L., Ndubisi, N. O., Pais Seles, R., & M., B. (2020). Sustainable development in Asian manufacturing SMEs: Progress and directions. *International Journal of Production Economics, 225*, 107567. https://doi.org/10.1016/j.ijpe.2019.107567
16. Del Vecchio, P., Secundo, G., Maruccia, Y., & Passiante, G. (2019). A system dynamic approach for the smart mobility of people: Implications in the age of big data. *Technological Forecasting and Social Change, 149*, 119771. https://doi.org/10.1016/j.techfore.2019.119771
17. Demiralay, S., Gencer, H. G., & Bayraci, S. (2021). How do artificial intelligence and robotics stocks co-move with traditional and alternative assets in the age of the 4th industrial revolution? Implications and insights for the COVID-19 period. *Technological Forecasting and Social Change, 171*, 120989. https://doi.org/10.1016/j.techfore.2021.120989
18. Dhahri, S., Slimani, S., & Omri, A. (2021). Behavioral entrepreneurship for achieving the sustainable development goals. *Technological Forecasting and Social Change, 165*, 120561. https://doi.org/10.1016/j.techfore.2020.120561
19. Di Vaio, A., Palladino, R., Hassan, R., & Escobar, O. (2020). Artificial intelligence and business models in the sustainable development goals perspective: A systematic literature review. *Journal of Business Research, 121*, 283-314. https://doi.org/10.1016/j.jbusres.2020.08.019
20. Fritz, M. M., Ruel, S., Kallmuenzer, A., & Harms, R. (2021). Sustainability management in supply chains: The role of familiness. *Technological Forecasting and Social Change, 173*, 121078. https://doi.org/10.1016/j.techfore.2021.121078
21. Grijalvo, M., Segura, A., & Núñez, Y. (2022). Computer-based business games in higher education: A proposal of a gamified learning framework. *Technological Forecasting and Social Change, 178*, 121597. https://doi.org/10.1016/j.techfore.2022.121597
22. Gupta, B. B., Gaurav, A., Panigrahi, P. K., & Arya, V. (2023). Analysis of artificial intelligence-based technologies and approaches on sustainable entrepreneurship. *Technological Forecasting and Social Change, 186*, 122152. https://doi.org/10.1016/j.techfore.2022.122152
23. Gupta, S., Kumar, V., & Karam, E. (2020). New-age technologies-driven social innovation: What, how, where, and why? *Industrial Marketing Management, 89*, 499-516. https://doi.org/10.1016/j.indmarman.2019.09.009
24. Haefner, N., Wincent, J., Parida, V., & Gassmann, O. (2021). Artificial intelligence and innovation management: A review, framework, and research agenda. *Technological Forecasting and Social Change, 162*, 120392. https://doi.org/10.1016/j.techfore.2020.120392

25. He, T., Liu, M. J., Phang, C. W., & Luo, J. (2022). Toward social enterprise sustainability: The role of digital hybridity. *Technological Forecasting and Social Change, 175*, 121360. https://doi.org/10.1016/j.techfore.2021.121360
26. Huang, M.-H., & Rust, R. T. (2018). Artificial intelligence in service. *Journal of Service Research, 21*(2), 155-172. https://doi.org/10.1177/1094670517752459
27. Johansen, D. F., & Vestvik, R. A. (2020). The cost of saving our ocean—Estimating the funding gap of sustainable development goal 14. *Marine Policy, 112*, 103783. https://doi.org/10.1016/j.marpol.2019.103783
28. Johnson, P. C., Laurell, C., Ots, M., & Sandström, C. (2022). Digital innovation and the effects of artificial intelligence on firms' research and development – automation or augmentation, exploration or exploitation? *Technological Forecasting and Social Change, 179*, 121636. https://doi.org/10.1016/j.techfore.2022.121636
29. Kabengele, C., & Hahn, R. (2021). Institutional and firm-level factors for mobile money adoption in emerging markets–A configurational analysis.
30. Lammers, T., Rashid, L., Kratzer, J., & Voinov, A. (2022). An analysis of the sustainability goals of digital technology start-ups in Berlin. *Technological Forecasting and Social Change, 185*, 122096. https://doi.org/10.1016/j.techfore.2022.122096
31. Qureshi, S. (2022). Harnessing knowledge networking for global capability sourcing: The development imperative. *Information Technology for Development, 28*(1), 1-15. https://doi.org/10.1080/02681102.2022.2022881
32. Prokopenko, O., Chechel, A., Koldovskiy, A., Kldiashvili, M. (2024). Innovative Models of Green Entrepreneurship: Social Impact on Sustainable Development of Local Economies. Economics Ecology Socium 8, 89–111. https://doi.org/10.61954/2616-7107/2024.8.1-8
33. Ranjbari, M., Shams Esfandabadi, Z., Zanetti, M. C., Scagnelli, S. D., Siebers, P.-O., Aghbashlo, M., Peng, W., Quatraro, F., & Tabatabaei, M. (2021). Three pillars of sustainability in the wake of COVID-19: A systematic review and future research agenda for sustainable development. *Journal of Cleaner Production, 297*, 126660. https://doi.org/10.1016/j.jclepro.2021.126660
34. Ricciardi, F., De Bernardi, P., & Cantino, V. (2020). System dynamics modeling as a circular process: The smart commons approach to impact management. *Technological Forecasting and Social Change, 151*, 119799. https://doi.org/10.1016/j.techfore.2019.119799
35. Richter, M. A., Hagenmaier, M., Bandte, O., Parida, V., & Wincent, J. (2022). Smart cities, urban mobility, and autonomous vehicles: How different cities need different sustainable investment strategies. *Technological Forecasting and Social Change, 184*, 121857. https://doi.org/10.1016/j.techfore.2022.121857
36. Rodríguez-Espíndola, O., Cuevas-Romo, A., Chowdhury, S., Díaz-Acevedo, N., Albores, P., Despoudi, S., Malesios, C., & Dey, P. (2022). The role of circular economy principles and sustainable-oriented innovation to enhance social, economic, and environmental performance: Evidence from Mexican SMEs. *International Journal of Production Economics, 248*, 108495. https://doi.org/10.1016/j.ijpe.2022.108495
37. Leal Filho, W., Wall, T., Rui Mucova, S. A., Nagy, G. J., Balogun, A.-L., Luetz, J. M., Ng, A. W., Kovaleva, M., Safiul Azam, F., Alves, F., Guevara, Z., Matandirotya, N. R., Skouloudis, A., Tzachor, A., Malakar, K., Gandhi, O. (2022). Deploying artificial intelligence for climate change

adaptation. *Technological Forecasting and Social Change, 180*, 121662. https://doi.org/10.1016/j.techfore.2022.121662

38. Lee, C.-C., Qin, S., & Li, Y. (2022). Does industrial robot application promote green technology innovation in the manufacturing industry? *Technological Forecasting and Social Change, 183*, 121893. https://doi.org/10.1016/j.techfore.2022.121893
39. Lehmann, J., Weber, F., Waldkirch, M., Graf-Vlachy, L., & König, A. (2022). Institutional work battles in the sharing economy: Unveiling actors and discursive strategies in media discourse. *Technological Forecasting and Social Change, 184*, 122002. https://doi.org/10.1016/j.techfore.2022.122002
40. UNDP. (2022). *Human Development Report 2021–22: Uncertain Times, Unsettled Lives: Shaping our Future in a Transforming World*. United Nations Development Programme. Retrieved from https://www.undp.org/egypt/publications/human-development-report-2021-22-uncertain-times-unsettled-lives-shaping-our-future-transforming-world
41. United Nations. (2022a). *THE 17 GOALS | Sustainable Development*. United Nations. Retrieved from https://sdgs.un.org/goals
42. United Nations. (2022b). *Sustainable development report 2021*. United Nations. Retrieved from https://dashboards.sdgindex.org/rankings
43. United Nations. (2022c). *About the sustainable development goals*. United Nations. Retrieved from https://www.un.org/sustainabledevelopment/sustainable-development-goals/
44. United Nations. (2022d). *Social development for sustainable development*. United Nations. Retrieved from https://www.un.org/development/desa/dspd/2030agenda-sdgs.html
45. WIPO. (2022). *Global Innovation Index 2021*. World Intellectual Property Organization. Retrieved from https://www.wipo.int/publications/en/details.jsp?id=4622
46. World Economic Forum. (2017). *Which countries are achieving the UN Sustainable Development Goals fastest?* World Economic Forum. Retrieved from https://www.weforum.org/agenda/2017/03/countries-achieving-un-sustainable-development-goals-fastest/
47. World Economic Forum. (2020). *The global risks report 2020*. World Economic Forum. Retrieved from https://www.weforum.org/reports/the-global-risks-report-2020
48. World Economic Forum. (2023). *The Global Economy will be $16 trillion bigger by 2030 thanks to AI*. World Economic Forum. Retrieved from https://www.weforum.org/agenda/2017/06/the-global-economy-will-be-14-bigger-in-2030-because-of-ai/
49. World Bank. (2023). World Bank's Fall 2023 Regional Economic Updates. URL: https://www.worldbank.org/en/news/press-release/2023/10/04/world-bank-fall-2023-regional-economic-updates (Date accessed: 5.11.2024).
50. European Union. (2022). URL: https://ec.europa.eu/info/research-and-innovation/strategy/strategy-2020-2024_en (Date accessed: 5.11.2024).
51. Research and Markets. (2022). URL: https://www.researchandmarkets.com/reports/5008078/big-data-market-with-covid-19-impact-analysis-by (Date accessed: 5.11.2024).

52. UK Department for Business, Energy and Industrial Strategy. (2022). URL: https://www.gov.uk/government/publications/uk-innovation-strategy-leading-the-future-by-creating-it (Date accessed: 5.11.2024).
53. US Department of State. (2022). URL: https://www.state.gov/innovation-roundtables/ (Date accessed: 5.11.2024).
54. International Monetary Fund. (2021). Global financial stability report update. Vaccine inoculate markets, but policy support is still. URL: https://www.imf.org/en/Publications/GFSR/Issues/2021/01/27/global-financial-stability-report-january-2021-update (Date accessed: 5.11.2024).
55. Financial Stability Board. (2020). The implications of climate change for financial stability. URL: https://www.fsb.org/uploads/P231120.pdf (Date accessed: 5.11.2024).

THE LEGAL ISSUE OF ENVIRONMENTAL COMPONENT WITH THE HELP OF DIGITAL TECHNOLOGIES ON THE EXAMPLE OF FORESTS

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Abstract

Research on and analysis of environmental damages to Ukraine during hostilities as well as related consequences to the environment caused by russian aggression. Methodological basis for the research was formed by the following methods: system-and-structure method, comparative, logic-and-juridical method, and scientific generalization method. Analysis of official data sources currently available for general public concerning the consequences of the russian military aggression in terms of damage inflicted on the environment of Ukraine. Study of research by environmental lawyers working in the area of environmental-and-legal security of a sovereign state under conditions of martial law. Accentuation on significance of introduction and development of modern digital (innovation) technologies for environmental safety of population and territories for securing a safe environment. Introduction of relevant amendments to the legislation is proposed due to arising of present-day challenges caused by warfare instigated by russian aggression. A research has been carried out on the example of the damage inflicted on the environment, in particular on forest resources. Problems have been outlined that arose following February 24, 2022 and persist till present day. Possible ways of solving the problems faced by Ukrainian state, the government and the people are proposed aimed at reducing the damage to the environment and people's health under conditions of the russia-Ukraine military conflict.

Keywords: *environment, technologies, digital technologies, forests.*

Introduction

According to the State Environmental Inspection of Ukraine (State environmental inspection, 2022), during two years of the russian military aggression the environment of Ukraine suffered damages by over UAH 1 trillion 743 billion. Sum total of losses from soil pollution and land contamination exceeds UAH 688 billion.

Atmospheric air pollution was estimated to inflict UAH 998 billion damage, while pollution and contamination of water resources has resulted in more than UAH 56 million losses. Between February

24, 2022 and January 24, 2024 period of russian invasion, territorial and regional agencies of the State Environmental Inspection recorded and calculated the quantitative measures of damages caused by the invaders (Fig. 1):

280,904 m2	of soils are polluted with hazardous substances
12,277,512 m2	of land are clogged with remnants of destroyed objects and munitions
686,816 tons	of oil products have burnt during shelling, polluting atmospheric air with toxic substances
33,132 hectares	of forests and other plantations have been burnt out by rockets and shells with possible restoration period of a decade for some of them by optimistic estimations, while others have been lost forever
1,063,947 m2	of objects, including those of critical infrastructure, have been destroyed, their ruins causing damage to the environment
1,597 tons	of pollutants got into water bodies
2,903,513 kg	of foreign objects, materials, wastes, and/or other substances that got into water bodies

Fig. 1. The quantitative measures of damages caused by the invaders
Source: authors development

Materials and methods

Forests play a key role in mitigating climate change by absorbing carbon dioxide. The EU is actively developing and implementing legal mechanisms to preserve forests and combat illegal logging. However, effective control and monitoring requires modern technologies such as satellite monitoring, drones, and artificial intelligence. The use of digital solutions, in turn, can significantly improve the efficiency of forest management, protection and monitoring of environmental violations. For example, platforms that process satellite data can help identify illegal logging or changes in forests.

As a result of full-fledged warfare, environmental problems experienced by Ukraine prior to its beginning have exacerbated extensively. Denial of access to territories and objects of environment management, loss and destruction of infrastructure, loss of personnel and limited ability to work, suspension of control measures for the period of martial law have negatively affected the possibility of proper implementation of state management in the field of environment protection. During the war, the need has arisen in estimating the damage to the environment caused by the war and the expenses on its restoration. Even at present stage, the scale of ecological crimes committed by russian invaders is astounding. Some eco-systems and unique objects are beyond restoration. With damage to the environment being evident, its estimation requires new approaches, because the full amount of damages and harm to nature presently remains unknown due to the monitoring systems being destroyed or damaged with access to forests and other territories being limited or non-existent. Recording of facts of environmental damage inflicted by the russian invasion is carried out within the operation of the “EcoZagroza” [EcoThreat] information panel and the work of the operational headquarters at the State Environmental Inspection (Draft plan on recovery of Ukraine, 2022).

The time is ripe today to think in advance of environmental crisis Ukraine and the world are facing. It is impossible not to mention the increased risks to life and health of people that we witness daily, like changes in weather conditions that trigger floods, draughts, earthquakes, etc., emergence of new migration processes, critical level of environmental dangers, depletion of natural resources and the loss of bio-diversity – all these factors lead to environmental catastrophe for all humankind, future generations included.

Currently, active warfare is observed in the east and the south of Ukraine. Part of Ukrainian lands is still under occupation, and on the liberated territories undertaking of large and long-term work on demining is needed. Thus, nearly half of Kharkiv region was occupied for comparatively long time, which affected negatively the state of various branches of the region's economy and agriculture, including its forestry and hunting business.

Results and discussion

At present, it is impossible to calculate precisely the damages inflicted on the environment. For this reason, President Volodymyr Zelenskiy at the COP27 platform has offered to form the Global platform for estimating the damages to the climate and the environment from military warfare. This is, obviously, a difficult task primarily for Ukraine, which is the first among the European continent states to take the road of defending and protecting the sovereignty, independence and territorial integrity of the state within its internationally recognized borders, the chosen European democratic direction of development, as well as vital national interests in the areas of power, food, environmental security, etc. (Getman & Anisimova, 2022; Anisimova, 2022).

Presently, Draft Plan on Renovation of Ukraine has been developed (materials by the "Environmental Safety" working group) (Draft plan on recovery of Ukraine, 2022) prepared by the National Council on Renovation of Ukraine after the war. The relevant section of the document defines 5 main areas: Climate policies: avoiding of and adapting to changes in climate; Environmental safety and efficient wastes management; Balanced use of natural resources under conditions of raised demand and limited supplies; Preserving the natural eco-systems and biological diversity, restoration and development of protected territories and objects; Efficient state management in the area of environment protection and use of nature resources. All of them in total define a clean and safe environment as their strategic goal and priority.

Nevertheless, the developed Draft Plan is devoid of instruments to implement the set goals. To attain their implementation, we consider it expedient to turn to the practices of the European Union states which accentuate on the role of digital technologies in achieving the goals of the Green Agreement through implementing digital solutions and the use of data that may assist in transition to a climatically neutral and sustainable economy (Goldstein, Turner, at al., 2020).

Digital technologies enhance more environmental-friendly processes in agriculture, power generation, construction, industry, etc. In view of this, the European Commission provisions that digital infrastructure and technologies are to become more energy- and resource efficient. Important accentuation is made on environmental standards and innovations (Savchuk, 2021) that enable enterprises to apply digital technologies with a lesser impact on environment in the course of digital

transformation (Savchuk, 2022; 2030 Digital Compass: The European Way For The Digital Decade, 2021).

One has to agree with the supposition that currently in Ukraine, digital transformation of economy is denied due attention in terms of its interaction with sustainable development issues, particularly such its constituent as natural environment protection. Despite its commitment to the post-war renovation on the principles of sustainable development, the draft materials by the "Digitalization" working group do not contain any provisions concerning the impact of digitalization on the environment. Meanwhile, the principle of promoting environment protection is to be the cornerstone in the foundation of forming the general strategy of the digital area development in Ukraine. This, in its turn, will define the peculiarities in implementation of the external policies of the state under digital transformation. Modern information-communication technologies can both facilitate development of new solutions to overcome an environmental crisis and, on the other hand, make a significant negative impact on the natural environment (Malolitneva, 2022).

Of utmost importance is development of digital technologies, apart from the mentioned above, in the forestry industry, which will enable simplifying management and control of business activities, remote and easy obtaining of various services, forming a transparent and comfortable digitalized environment. Compilation of a 3-D forests map will enable automatic data collection on the wood (species composition, diameter and height) by using a well established all over the world technology of remote sensing by means of laser pulses (LIDAR). This technology will also enable performing very precise calculations as to how much wood can be harvested from this or other plot of woodland. Along with the digital map of forests, these survey data will be integrated into the EOD (from Ukrainian Digitalized Wood Accounting) system (Digital revolution. The open forest, 2023).

Since February 24, 2022, more than 40 thousand hectares of forest territories of Ukraine were engulfed by fires. Half of this area pertains to the Chornobyl biosphere reserve. Overall, due to military warfare in Ukraine, 20% of protected natural reserves of Ukraine have suffered, their area approaching one million hectares. Besides, 2.9 million hectares of the Emerald Chain are in the risk zone, while 16 Ramsar objects with the area of nearly 600 thousand hectares are under threat of total destruction. Forest fires also cause irreparable damage to Ukrainian biodiversity because fire destroys everything in its path (Donets, 2022).

In part of the territory of forest resources which was in 2022 temporally out of control of Ukraine, forest areas, primarily pine forests, were completely destroyed or suffered significant damage, which in its turn could not fail to have an effect on ecological balance of the affected areas. For better understanding of the warfare consequences, let us pause at analyzing some aspects of forestry and hunting industry on the example of Kharkiv region.

Thus, according to the state forest cadastre, the total area of forests and other forested zones in Kharkiv region amounts to 419.4 thousand hectares. The forest cover index of the area prior 24.02.2022 was 12.1%. Total stock of wood in the forests of the area prior to the beginning of the russian aggression was accounted in the volume of more than 68.0 million cubic meters.

Most of the forest lands in the area (324.9 thousand hectares or 77.5%) is subordinated to the State Forestry Agency of Ukraine. The authorized body of the State Forestry Agency in the region is the North-Eastern Interregional Department of Forestry and Hunting. 301.4 thousand hectares of the forest resources lands are in permanent use by state enterprises.

In order to ensure forests protection, work of 309 state forest protection personnel was organized at subordinate forestry enterprises (there were 506 employees in 2021 with a staff of 597). Cooperation with law enforcement agencies in matters of forest protection was established.

The main problem in forestry business operation is impossibility of restoring full-fledged operation of the enterprises on the de-occupied territories and in the active combat areas. Of the total forest areas of the region, 7.2 thousand hectares are temporally under occupation. 170.6 thousand hectares of forest lands require works on pyrotechnic survey, including demining. Demining works have been carried out on the area of only 616 hectares.

Considering the above, it is impossible to carry out inspection measures for forests protection and establish all cases of forest fires and illegal felling in the specified territories until the end of hostilities and forests demining. In the territories that can be surveyed, 47.4 hectares of forests destroyed by fires, 1509.75 hectares of forests damaged by fires, 1831 m3 of illegal felling were documented.

During 2022, 136 forest fires were documented in the Department's forests on the area of 1568.72 hectares. The area of crown fires amounted to 47.4 hectares, the average fire area being 11.53 hectares.

In 19 cases, the firefighting personnel of the Main Department of the State Emergency Service of Ukraine in Kharkiv region were involved in extinguishing forest fires. Information on the number of forest fires, their area and the amount of the inflicted damage will be established after hostilities termination, demining of territories and carrying out instrumental survey of the burnt-out areas.

Out of the total number of forest fires, 105 cases were caused by warfare. In most of these cases, there was no possibility to carry out works on extinguishing the fires, they burnt out on their own. All materials on forest fires have been submitted to law enforcement bodies. Materials on forest fires caused by warfare are also sent to the State Environmental Inspection in Kharkiv region.

Compared to year 2021 (when 91 fires on the area of 32.67 hectares with the average area being 0.36 hectares were recorded), the increase in fires during last year [2022] is the following: by the number of fires – 149%, by area – 4802%, by average area – 3303%.

When analyzing the distance land probing data, about 2 thousand cases of thermal anomalies were established on the previously uncontrolled territories which presently need demining. The area of the mentioned fires may amount to 20 thousand hectares, in which case the total damage will exceed UAH 100.0 billion. As a result of the armed aggression, the "Iziumske Forestry" state enterprise and the "Kupiansk Forestry" state enterprise have lost practically all fire extinguishing vehicles and equipment, considerable losses were inflicted on the "Vovchanske Forestry" state enterprise and the "Chuhuyev-Babchanske Forestry" branch of the "Forests of Ukraine" state enterprise.

Due to economic losses, plans were not implemented concerning replenishment and renovation of fire extinguishing equipment and inventory, there is no finance on performing fire-prevention and other forest protection measures in full volume. With no financing for fire-prevention and forest protection works and patrolling forest lands, forestry enterprises are unable to renovate fire-fighting equipment and inventories as required, to carry out monitoring of occurrence of forest fires, to arrange and maintain mineralized belts, to keep and ensure operation of forest stations and observation points, to keep temporary fire wardens, to arrange recreation areas, to extinguish forest fires and to carry out anti-fire propaganda.

In order to fulfill the tasks on forests protection from fires, to ensure elimination of consequences of forest fires and to prevent their occurrence in future, there is an urgent need in allotment of the

following equipment to the enterprises that suffered most during the warfare: 25 fire engines, 13 patrol cars and small forest-fire complexes, 14 tractors for arranging anti-fire mineralized belts. Besides, due to combat actions, measures to improve the sanitary state of forest were carried out in 2022 on the area of 6 thousand hectares, which is twice less than in 2021.

At present, the most acute problem is that of pollution of forested territories with explosive objects. This factor affects not only work safety of forestry employees but also the opportunity of using the plots of forestland determined by forest arrangement plans for wood-harvesting. Part of the Kharkiv region forestry enterprises are unable to carry out in practice the measures on improvement of forests sanitary state, which are planned in order to protect forests by means of performing relevant forest-business works. Untimely sanitation of forests can result in a negative impact on natural environment. Fulfillment by of felling plans to form and sanitize forests and main use cuttings by forestry enterprises is a token of rhythmical work of forest businesses including the work concerning relevant forest management measures on growing highly productive plantations, guarding and protection of forests. Also, a timely, quality and substantiated wood cutting forms condition for avoiding various violations and prevention of social tension in communities concerning illegal felling, etc.

Combat actions started by the russian federation military aggression February, 2022 have led to an abrupt (by 286,877.0 m3 or by 50%) decrease in wood-harvesting specified by forest arrangement plan in 2022 as compared to the previous year, including:

- forest-formation and forest sanitation cuttings by 252,506.0 m3 or by 49%;
- wood-cuttings related to care of young trees were undertaken on the area of only 477 hectares compared with 1123 hectares in 2021.

Overall, wood-care cuttings were performed by forestry employees on the area of 1263 hectares, which is 2298 hectares or 65% less than the preceding year.

Many plantations that had reached the ripe age and were suit for business felling were lost partially or completely. The mentioned type of cuttings has two goals: wood-harvesting to satisfy needs of different branches of industry and changing of ripe plantations by a new, young generation of trees. Observing these principles ensures timely, sustainable, continuous and non-extensive forest use with subsequent restoration of forests on the felled areas which ensures stability of forest environments.

Thus, in 2022 the amount of wood-harvesting by business felling was 8595 m3, which is nearly 80% less compared with 2021(40,412 m3).

The beginning of hostilities in 2022 coincided with the preparations of forestry enterprises in Kharkiv region for the spring campaign of implementing the environmental initiative “Mass-scale Forestation of Ukraine” to fulfill the Edict of the President of Ukraine of 07.06.2021 № 228/2021 “On Measures on Forests Preservation and Restoration”. The planned events were not carried out in preliminary estimated amounts.

In 2022, it was planned by state forestry enterprises that were coordinated by Kharkiv Regional Administration of Forestry and Hunting to restore forest on the territory of 673.73 hectares, but due to the full-scale invasion by the russian federation and partial occupation of the region, it was impossible to carry out forest-culture works (forest restoration, forest-planting) on the area of 438.4 hectares.

Last [2022] year it was impossible to perform care of forest cultures, seedlings and saplings in forest nurseries and greenhouses, soil cultivation, and replenishment of forest cultures. Harvesting of forest seeds was not made either due to mine danger (Forest Resources Assessment (FRA), 2020).

By the outcomes of the 2022 autumn inventory and attestation, 2,667.3 hectares of forest cultures were not accounted for due to combat actions. It was impossible to take stock of the available planting material for main forest-forming species in hothouses and forest nurseries as well as decorative saplings at school branches and at plantations. Forest-covered area of 518.8 hectares was not transferred to forest lands, of them 498 hectares pertaining to the state forest resources and 20.8 hectares – to the areas of natural renovation.

As to hunting business of the region, the total area of hunting grounds as of 01.01.2022 was 2 million 631 thousand hectares, of which: 1 million 659 thousand hectares were allotted for use to 40 organizations – 63.1% of the lands of the region, while lands of the state hunting reserve (or spare) amount to 972 thousand hectares or 36.9% of the regional lands. According to preliminary information (until completion of demining and carrying out extensive survey of lands), the territory of hunting grounds allotted for use to 25 renters with the total area of 899.1 thousand hectares is currently in the active combat zone and has suffered impact of various extent, of them 842.5 thousand hectares (23 renters) were under occupation and partially remain so up to now. There is no connection with four hunting grounds users.

Access to the larger part of the mentioned hunting grounds is impossible, which in its turn renders it impossible for hunting grounds users to carry out hunting-and-economic work, taking stock of hunting animals and calculating the damages inflicted by the armed aggression by the russian federation.

In order to secure hunting grounds and lands of the state hunting reserve (or spare) in Kharkiv region and to prevent poaching, employees of state forestry enterprises organize raids on the territories of Kharkiv region's hunting grounds. Thus, since the beginning of this [2023] year, 7 raids have been made, which is 70% less compared with the same period in 2022. Impossibility of carrying out raid work in the larger part of the region is related exclusively with the mining of the territories and active combat.

In order to provide firewood to the population of the territories adjacent to the active combat zone, the Cabinet of Ministers of Ukraine in support of the initiative by the Ministry of Integration approved subventions distribution from the State to local budgets. By the end of 2022, the regions of Ukraine had mastered the allotted funds in the amount of UAH 524.5 million, which made 93% of the subvention. Currently, delivery and distribution of firewood to frontline territories residents is underway, which will enable them to survive winter in warm houses. Also, 199,000 m3 of firewood were delivered to territorial communities in frontline regions of Ukraine throughout 2022, of which 151,000 m3 were distributed among households with door-to-door delivery. More than 35,000 families on the territory of the region got free firewood for warming their dwellings during the winter period.

Kharkiv region in this respect is not an exception. Forestry enterprises in the region also did substantial work on harvesting and supplying firewood to fulfill the mentioned subvention within the allotted funds. Thus, initial fulfillment of this program in Kharkiv region amounted to UAH 66 million in 2022. Also, Kharkiv region was granted additional subvention on account of funds that hadn't been used by other regions.

The full-fledged military invasion of the russian federation into the territory of Ukraine has led to substantial impact of military actions on supplying firewood to the population of the region; apart from that it also has formed conditions and demand for supplying a wide range of timber for the needs of the Armed Forces of Ukraine (ZSU). At the same time, military actions on the territories of certain

local communities in Kharkiv region and a number of territories adjacent to the state border of Ukraine with the russian federation that suffer permanently from shelling make it impossible to carry out wood-harvesting works safely in the mentioned zones. As a result, firewood supplies to population in these localities have to be made with taking into consideration the frontline logistics as well as real needs concerning address delivery to the homesteads whose residents need such help acutely.

Provision to the ZSU of forestry products, including firewood and lumber, is carried out by regional forestry enterprises in accordance with the procedure for lumber conscription as provisioned by the Law of Ukraine "On the transfer, forced alienation or seizure of property in the conditions of the legal regime, martial law, or state of emergency".

For the needs of the ZSU, 10,659 m3 of lumber were supplied in 2022, while this year – 907 m3. Presently, interaction between the regional forestry enterprises and ZSU units on the mentioned issues goes on as prescribed by law.

The state government implements a set of measures aimed at ensuring inevitability of bringing the russian federation to justice. It is military actions that have set new challenges and caused the state to search for new approaches to ensure responsibility of the aggressor country for damages inflicted on the environment of Ukraine. The Ministry of Environment has done its best to reflect these approaches in methodologies for determining losses and damage caused by armed aggression and hostilities. Presently, six methodologies for calculating damages to the environment components have been approved.

Losses of the forest resources due to the armed aggression by the russian federation include the damage inflicted on the state and the damage caused to permanent users of forests and forest owners on plots of lands allotted to forestry business, linear protective plantings, forest nurseries, forest cultures, and hunting grounds users.

The complexity of calculating the inflicted damage in Kharkiv region is that substantial part of forested territories and hunting grounds remain mined, and some areas are still under occupation.

Presently, preliminary calculations have been published by:

- The State Environmental Inspection in Kharkiv region on cases of forest fires that occurred due the russian aggression. Estimated damages are UAH 3.3 billion;
- specialists of forestry enterprises in Kharkiv region on damages caused by forest fires and illegal felling. Estimated damage is UAH 407 million and UAH 28 million respectively;
- Kharkiv interdistrict UTMR (Ukrainian Society of Hunters and Fishermen) organization on damages caused to hunting business. Estimated damage is UAH 238 thousand.

Comprehensive calculation of forestry industry losses caused by rights limitation to permanent land-users and the loss of damaged harvested lumber, revenues not received by forest users from temporary occupation of land plots, failure to carry out felling for main use and felling for forests formation and improvement in the volumes determined by forest management plans (Campbell N., 2022; Maschietto E., 2021), expenses on soil preparation and forest cultures formation, saplings growing in forest nurseries and care of them, losses of hunting enterprises due to destruction of or damages to enclosures, other biotechnical constructions, wild animals, etc. will be possible only following termination of hostilities and carrying out pyrotechnic examinations (including demining) of the forested territories and hunting grounds in the region.

Today, the following problematic issues regarding forestry and hunting management in the region persist:

- very low rates of pyrotechnic inspection of forests including demining, which significantly decreases the rates of or makes wood-harvesting impossible, forest-forming and sanitation cutting included;
- lack of forestry specialists at state forestry enterprises owing to their evacuation to safe regions of Ukraine or to Europe in 2022, which considerably decreases quality of forestry business practices from the standpoint of current forest and other environment protection legislation of Ukraine on the de-occupied territories;
- impossibility of soil preparation on solid cuttings of 2021 and 2024 to form forest cultures – new young generation of forest;
- available risk of losing a large amount (on the scale of millions of saplings) of the grown planting material of the main forest-forming species (pine and oak) due to impossibility of planting it on the forested areas of the de-occupied territories;
- impossibility of full-fledged performing of field works on basic forest formation in the forests of the mentioned enterprises, which slows down full and legally substantiated forestry management for the middle- and long-term perspective;
- absence of the possibility of fulfillment of forest-pathology and sanitation inspections of forests by forestry specialists, which is urgent due to destruction of Slobozhanschina (Kharkiv region) pine forests by the russian federation troops;
- impossibility of carrying out inspection measures to establish all cases of forest fires and illegal felling on de-occupied territories;
- raise in cases of forest fires due to warfare and impossibility of fire-fighting works;
- raise in cases of arbitrary felling as a result of difficult socio-economic circumstances for the population;
- lack of actual data on state inventory of all forests in the region regardless of form of property and administrative subordination as well as those not allotted to renters in the region, which does not allow determining the initial indicators for further forestry development in the region, including works on restoration of forests damaged during active combat;
- negative perspectives as to increase in areas of the hunting reserve lands in the region due to impossibility of further running hunting business by the regional UTMP (Ukrainian Society of Hunters and Fishermen) and other users in the active combat zone;
- impossibility of making comprehensive calculations (Krämer L., 2020) of damage and losses suffered by hunting business in the region due to armed aggression by the russian federation.

Conclusions

At present, we are partly losing Ukrainian forests and other precious territories due to combat actions. Decades are needed to restore them. Logical and necessary for a short- and medium-term perspective ways to revive forestry and hunting businesses and prospective areas for their development in the region are:

- conducting pyrotechnic examinations including demining of forested lands and industrial venues of forestry enterprises in the priority order for such measures;
- conducting the survey of the extent of damage to forest environments due to temporary occupation;
- estimating the damages suffered by permanent forest users including due to pollution of forested lands with foreign materials, wastes, or other substances;
- performing an analysis as to the amounts of needed seasonal forest-culture works (prognostication of areas needed to form forest cultures, areas where work on soil cultivation and care of forest cultures is needed);
- survey of nature reserves territories and objects that have suffered as a result of active combat and establishing the damage inflicted on them;
- a detailed, quality and extensive survey of lands at he territorial (local) communities level to identify self-forested lands and the lands suitable for forestation with their subsequent transfer to forestry lands through the procedure of allotting them to land-users;
- conducting state accounting of all forests regardless of their administrative subordination and form of property, because only its outcomes will make it possible to obtain actual information on the forest areas, the amount and real reserves of wood in them, as well as availability of users or owners;
- attaching (granting for use) of all "nobody's" forests in the region to land-users (renters);
- development of a mechanism to encourage private landowners to implement a comprehensive system of combating soil erosion, including through the creation of protective forest plantations;
- introduction of modern digital (innovation) technologies in forest-growing, carrying out sanitation cuttings when tending to forests and in wood-harvesting, guarding and protection of forests;
- facilitating forest recreation and green tourism development;
- ensuring state support, improvement of the system for firefighting in the forests of all forms of property;
- following termination of hostilities and carrying out relevant surveys, designing a regional (local) program for guarding, protection, use and restoration of forest and hunting business development;
- designing a regional (local) program aimed at providing firewood to the population, enterprises, offices, organizations and business including on account of technological processing into chips, briquettes, etc. of non-liquid underbrush at forest cuts;
- designing a relevant regional (local) program aimed at development of hunting business;
- determining financial sources including international ones together with ways of their targeted use for reviving forest environments;
- conducting relevant economic measures on renovation and development of forestry and hunting businesses.

References

1. 2030 Digital Compass: the European way for the Digital Decade. (2021). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee of the regions. Retrieved from https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A52021DC0118
2. Anisimova, G. V. (2022). Securing of environmental safety, and citizens' life and health under martial law: environmental- and legal aspects. Issues of Legality, (157), 93–115.
3. Campbell, N. (2022). Individual rights and the environmental public interest: A comparison of German and Chinese approaches to environmental litigation. Review of European, Comparative & International Environmental Law, 1(32): 105-118. DOI: https://doi.org/10.1111/reel.12466
4. Digital revolution. The open forest. (2023). Retrieved from https://www.openforest.org.ua/244344/.
5. Donets, O. V. (2022). Peculiarites of post-ware revival of Ukraine: the environmental- and legal aspect. Environmental- and legal security of a sovereign state under martial law with Proceedings of the Scientific and Practical Online Conference. December 8, 2022, Kharkiv, Ukraine.
6. Draft Plan on Recovery of Ukraine. (2022). Materials of the "Environmental Safety" work group. Retrieved from https://www.kmu.gov.ua/storage/app/sites/1/recoveryrada/ua/environmental-safety-assembly.pdf
7. Forest Resources Assessment (FRA). (2020). Côted'Ivoire Country Report. Rome. Overview. Available online at: https://www.fao.org/3/cb0126fr/cb0126fr.pdf
8. Getman, A. P. & Anisimova, G. V. (2022). Environmental and climate legal policy formation under the Russian military aggression: New doctrinal approaches. Environmental- and legal security of a sovereign state under martial law with Proceedings of the Scientific and Practical Online Conference. December 8, 2022, Kharkiv, Ukraine.
9. Goldstein, A., Turner, W.R., Spawn, S.A., Anderson-Teixeira, K.J., Cook-Patton, S., Fargione, J., Gibbs, H.K., Griscom, B., Hewson, J.H., Howard, J.F. and Ledezma, J.C. 2020. Protecting irrecoverable carbon in Earth's ecosystems. Nature Climate Change, 10(4): 287-295. DOI: https://doi.org/10.1038/s41558-020-0738-8
10. Krämer, L. (2020). Environmental Justice and European Union Law. Croatian Yearbook of European Law and Policy, 16: 1–23. DOI: https://doi.org/10.3935/cyelp.16.2020.369
11. Malolitneva, V. K. (2022). Promoting environment protection as a principle of implementine Ukraine's foreign policy under transformation. Environmental- and legal security of a sovereign state under martial law with Proceedings of the Scientific and Practical Online Conference. December 8, 2022, Kharkiv, Ukraine.
12. Maschietto, E. (2021). Environmental Law and Practice in Italy: Overview. Available online at: https://uk.practicallaw.thomsonreuters.com/1-5032608?transitionType=Default&contextData=(sc.Default)
13. Savchuk, O. O. (2021). Legal regulation of innovative technologies as an instrument of legal relations operation and environment protection. The MGU Science Bulletin. Section "Law", (54, vol. 1), 111–115. Retrieved from http://vestnik-pravo.mgu.od.ua/archive/juspradenc54/part_1/26.pdf

14. Savchuk, O. O. (2022). Legal issues of innovative technologies of environment use and protection. International Forum: Problems and Scientific Solutions with Proceedings of the 9th International Scientific and Practical Conference. February 6-8, 2022, Melbourne, Australia. Retrieved from https://ojs.ukrlogos.in.ua/index.php/interconf/issue/view/6-8.02.2022/716
15. State Environmental Inspection. Official site. (2022). Retrieved from https://dei.gov.ua/

INTERNET THINGS, GREEN LOGISTICS AND GREEN MARKETING FEATURES

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Abstract

The article analyzes that the Internet of Things are objects that combine sensory advances, can communicate with each other without human intervention, and recently become an extremely important and widespread service. Combining resources in green logistics creates an opportunity to align the Internet of Things with current business operations processes, reducing resources and costs and improving process management in various sectors such as transport. The Internet of Things has been highly promoted recently and helps speed up logistics processes. Business participants are informed about this using green marketing tools.

Keywords: *internet things, green logistics, green marketing.*

Introduction

According to European Commission research, the demand for organic products among consumers in the European Union has increased by 69 percent over the past 20 years. The public opinion poll commissioned by the State Consumer Rights Protection Service shows that as many as 59 percent It is important for Lithuanian consumers whether they buy a product from a company that contributes to the promotion of environmentally friendly consumption. The latter statistics became the reason for the increase of another number, i.e. i.e. for the number of businesses seeking to improve their environmentally focused image while increasing their profits. For this reason, environmentalism has become a very popular marketing ploy for businesses, and consumers are all too often exposed to unfair commercial practices. The Internet of Things consists of small to medium-sized objects, often specialized and with low or very low computing and communication capabilities.

The purpose of this article is to examine the functions of the Internet of Things, Green Logistics, and Green Marketing

A scientific question. The scientific question is as follows: are of Internet of Things, Green Logistics, and Green Marketing well-developed?

Research methods. The article is based on an analysis of scientific literature, statistical data and case study methods.

Research Methodology - Analysis of scientific literature, statistical data analysis, and case study is used in the article.

Practical implications. The practical significance of the Internet of Things in connection with green logistics and green marketing is great. The number of IoT devices worldwide has already exceeded the population of our planet. Many new cars are becoming part of the Internet of Things - it is convenient to check where the car was left, turn on the heating, and check the battery charge level, fuel consumption, or technical parameters of the car by phone.

Internet of Things

The Internet of Things means that all smart things can be controlled by a smartphone, watch, or computer from anywhere in the world. The Internet of Things consists of smart devices connected via a computer network, capable of interacting with each other without an intermediary. The main requirement is the ability to interact with each other. An Internet of Things device can be both a video camera that sends a message to the user after detecting movement, and a simple home router.

Savukynas et al. (2017) stated that in the context of the Internet of Things, a thing is considered a physical or informational world an object that can be identified and integrated into communication networks. Physical objects usually exist in the physical world, and information about them is obtained through stimulated and connected sensors.

Ghashim et al. (2023) mentioned that the Internet of Things is the interconnection of physical objects, while Mansour et al. (2023) and Mansour et al. (2016) considered the Internet of Things (IoT) as a global network of interconnected devices capable of exchanging data and information across various networks.

Chataut et al. (2023) argued that the rapid growth in technology and computer system capabilities was greatly influenced by the development of Internet of Things technology, while Oladimeji et al. (2023) mentioned that the Internet of Things (IoT) connects various smart devices to exchange data.

Zantalis et al. (2019) suggested that using in-vehicle sensors or mobile devices and city-mounted devices can offer optimized route suggestions, easy parking reservation, accident prevention and autonomous driving, while Twahirwa et al. (2022) defines a vehicle network that uses IoT devices.

Musa et al. (2023) mentioned that cargo management includes the ability to track vehicles, predict routes, departure points and destinations, travel schedules, detect alternative routes and manage fuel consumption using satellite and radio technologies that allow them to be deployed in specific geographic locations.

Khan et al. (2023) believed that IoT enables real-time monitoring of every step in the chain, while Mejjaouli, S. (2022) argued that connected devices must be able to interact with each other to benefit from IoT.

Chen et al. (2022) analyzed that with the rapid development of online commerce, consumers are increasingly choosing people-oriented logistics industry services.

Ntaflouk et al. (2023) mentioned that IoT devices, located in physical space, are part of the sensor layer for the joint detection, collection, and processing of data.

Long (2022) stated that the most important IoT technologies are radio frequency identification technology; nanotechnology, which is mostly used in sensors, radio frequency identification equipment; wireless sensors that ensure data collection and transmission even in the absence of a wired connection; machine - machine-to-machine technology, according to a set program, ensuring communication between machines and people; cloud computing and its security technologies; data synthesis technology, which provides the organization of data information by selecting information that best meets the needs of users.

Table 1 show different Internet of Things definition and comparison.

Table 1. Internet of Things definition comparison

Author	**Highlights**
Lombardi et al. (2021)	system of interconnected devices among themselves, equipped with computing capabilities (smart objects), identify and allow data to be transferred over a network without the need for human interaction.
Ali et al. (2022)	IoT devices and applications are deployed in various fields such as logistics, and retail.
Paolone et al. (2022)	physical objects ("things") that connect to the Internet and other things.
Rashvand et al. (2024)	highlights the importance of balancing model size and performance, which is critical for deployments in resource-constrained environments such as IoT devices.
Dhanaraju et al. (2022)	foresees that Internet of Things technologies play a crucial role in many farming activities, such as the use of communication infrastructure, data collection, smart objects, sensors, mobile devices, cloud-based intelligence, decision making, and automation of agricultural operations.
Hamdan et al. (2020)	IoT data is constantly transferred from applications to a central storage device, which is usually located in the cloud center. Some IoT applications require low latency and may require real-time processing. Handling such requirements using cloud computing is not appropriate.
Al Khatib et al. (2024)	can set details platforms connecting various smart devices.
Mashayekhy et al. (2022)	It is a strong connection between the physical and digital worlds, used in various fields to make goods, operations, and services smarter in the value chain, offering new possible solutions to change their functions.
Zeeshan et al. (2022)	The Internet of Things is a technology that collects information in the form of data and transmits it to other devices connected via the Internet.
Cano-Suñén et al. (2023)	IoT ecosystems require highly skilled technical staff, ongoing management (for calibration and monitoring), leaders who know how to digitize, and analysts with data-driven vision to derive operational insights.
Farhan et al. (2021)	The core vision of IoT is to provide a multitude of smarts devices together in integrated and interconnected heterogeneous networks, making the Internet seamless more useful.
Farias da Costa et al. (2021)	The Internet of Everything (IoE) is advancing and enriching people exists to add value.

Source: authors development

Summarizing the opinion of scientists, what is the Internet of things, it can be said that it is a system of interconnected devices equipped with computing capabilities (smart objects), a network of billions of devices that can sense, activate and transmit information to a centralized system, physical objects ("things"), that connect to the Internet and other things, ecosystem, IoT technologies play a crucial role

in many farming activities, such as the use of communication infrastructure, data collection, smart objects, sensors, mobile devices. devices, cloud-based intelligence, decision-making and automation of agricultural operations. The IoT must provide a multitude of smart devices in integrated and interconnected heterogeneous networks, making the Internet smoother and more useful.

Green logistics in the modern tendency

Transport must harmoniously integrate into sustainable transport chains, thus creating not only a more convenient, more enabling, but also a greener transport infrastructure. Green electricity from renewable energy sources is used in transport. Such a decision not only makes the EU cleaner but also contributes to the development of green energy production capacity. As market participants implement sustainable solutions in their daily activities, there will soon be more green energy than there is now.
Paužuolienė et al. (2022) state that the implementation of green logistics increases the quantity of delivered goods, better utilization of capacities, promotes the quality of products or services, increases the variety of goods, and reduces the amount of waste.
Plaza-Úbeda et al. (2021) argued that the concept of supply chain management has become "greener" through the development of reverse logistics programs, among other practices, to reduce costs and improve operational efficiency.
Klumpp (2016) mentioned that one of the most encouraging areas of green logistics is the development of technology that will lead to more transport that uses less energy and emits fewer pollutants.
Singh et al. (2020) mentioned that IoT can work on two fronts to make logistics green: the first involves the design of energy-efficient elements of the Internet of Things such as identification, sensing, communication protocols, computing, and network architectures to connect physical objects, and the second is to implement IoT-based technologies to reduce the negative impact of logistics operations.
The number of articles on the use of the Internet of Things is increasing in the scientific literature. Govindan et al. (2018) examine the importance of big data analytics and its applications in logistics and supply chain management. Kaur and Singh (2016) presented a sustainable supply chain model using big data. Katal et al. (2013) examined various related issues in big data such as standardization, tools, features, sources, and best practices.
Panavė et al. (2023) mentioned that to select the Internet of Things for research criteria for use in logistics, which statistically have significance and according to them data are collected in many European countries and stored in the "Eurostat" database. 1. Innovations in logistics include all innovations introduced in this field. 2. Internet of things for production processes and logistics management. 3. Management of logistics process communication means, sensors. Delves into the logistics management part, which is related to direct activities. 4. Internet of things premises to ensure safety. 5. Internet of things machines and vehicle maintenance. 6. Internet of things to manage energy consumption. 7. Internet of Things on costs pressure. 8. Internet of Things in response to regulation of business performance. According to Panavė et al. (2023) business in every country the execution may be similar but also very different. In more economically developed countries and business invests in advanced business management models, implements innovations. For big and strong companies, it can to be common, but innovation is not always a priority for smaller-cap companies. When conducting

international business, it is necessary to know the requirements of other countries or societies. There may be state or legal regulation.

Table 2. Internet of Things in logistics

Author	**Highlights**
Kvak et al. (2024)	the IoT is having a profound impact on distribution logistics, changing traditional practices and providing tracking and management, and helping companies meet customer expectations
Mo et al. (2022)	in developing the proposed reverse logistics system with IoT for service parts management, it is very important to identify the characteristics of service parts management from the point of view of supply chain planning and compared to advance logistics planning for products, the characteristics of maintenance parts planning include a large variety of storage units, low parts usage, high inventory criticality, and long component life cycles.
Brochado et al. (2024)	influenced by common data-sharing limitations among logistics players, preventing the customer from properly identifying the best logistics solutions available.
Mostafa et al. (2019)	implications of using IoT in SCM to create a simple analytics basis.
Rejeb et al. (2024)	the integration of IoT into the field of HL offers many opportunities to improve supply chain visibility and optimize aid distribution.
Šulyová et al. (2020)	favorable conditions for the implementation of IoT in logistics include: the sector being the first to adopt innovations, the development of 5G networks, better components, the use of big data, more customer demands, the daily generation of large amounts of data through applications.
Alzahrani et al. (2023)	the Internet of Things (IoT) has made significant progress in the logistics sector, especially in the areas of logistics warehouse management, communication systems, service quality, and supply chain management.
Prajapati et al. (2022)	supply chain management (SCM) is play a vital role in meeting the needs of consumers in the supply chain.
Jarašūnienė et al. (2023)	a technology designed to process large amounts of data with maximum efficiency in real time.
Mashat et al. (2024)	The Internet of Things (IoT), as one of the enabling technologies, plays an important role in improving organizational performance through supply chain integration.

Source: authors development

Summing up the researchers' opinion, IoT has a great impact on distribution logistics, changes traditional practices and provides new opportunities to improve efficiency, tracking and management, and helps companies meet customer expectations without negative investment impacts.

Green marketing

As the interest in environmental issues increases, the importance of green marketing gradually increases, and the possibilities of using green marketing increase. Interest in green marketing began in the 20th century and has grown even stronger in the 21st century. Various researchers examine green marketing as green marketing, ecological marketing, and sustainability marketing.

Green marketing was interested in scientific literature in the 8-9 decades of the 20th century. The negative impacts they have started to be researched. Green products with green packaging that protect the environment have been developed. European Center for Quality Ltd Bulgaria (2016) states that the United Nations Environment Program assigns a particularly important role to the green economy, which contributes to the eradication of poverty and sustainable economic growth, and the promotion of social inclusion, so should also support a healthy earth ecosystem operation. European Center for Quality Ltd Bulgaria (2016) states that the green economy will strengthen our ability to sustainably manage natural resources with less negative impact on the environment, increase efficient use of resources, and reduce waste.

Environmental protection problems have recently been relevant on a global and Lithuanian scale. This is influenced by the increasing number of people in the world and their interference with nature. Therefore, such sciences as green marketing and green logistics play an important role in the world.

Vilkaitė-Vaitonė and Skačkauskienė (2022) mentioned that Green marketing has the potential to benefit an organization, environment, and society. In scientific literature, commercial benefits for the organization are usually emphasized.

European Center for Quality Ltd Bulgarija (2016) stated that in addressing the problem of environmentally sustainable development, it is necessary to promote the protection and sustainable use of natural resources and ecosystems, the renewal of natural resources, and the fostering of sustainable, integrated, and appropriate global growth, it is very important to take urgent action against harmful production and non-organic consumption.

Alkhatib et al. (2023) mentioned that green marketing focuses on the promotion of environmentally friendly products, the perspective of sustainable marketing is broader and includes the involvement of the entire community.

Kiyak et al. (2023) argued that green marketing and environmental sustainability will have a significant impact on consumer purchasing and consumption habits in the future.

Baužytė (2020) considered that ecological marketing is also called green marketing. According to Baužytė (2020) green marketing is similar to conventional marketing, the only difference is that green marketing includes activities that which is related to environmentally safe products and services that can meet the environmental needs of consumers, production, differentiation, pricing, and advertising.

Wu et al. (2016) analyze that green marketing is an organization's commitment to creating environmentally safe, ecological goods or services. According to Wu et al. (2016) green marketing includes - purchasing, production, packaging, transportation, distribution, and waste disposal.

Pancić et al. (2023) mentioned that green marketing has become a strategy to respond to consumer demand for sustainable products and services and to maintain competitive advantage.

Kaur et al. (2022) stated that nowadays it is important to produce only organic products that do not harm the environment and its inhabitants.

Esmaelnezhad et al. (2023) and Strandhagen et al. (2017) considered that green products have positive properties, for example, they do not harm the environment and preserve it; they benefit public health; and their quality is better.

Yang et al. (2022) mentioned that companies engaged in green marketing aim to satisfy customers' needs for "green" goods and services.

Amaya Rivas et al. (2022) argued that green marketing (green products, price, location, etc. promotions) played a key role in addressing consumer concerns about the environment and the need for green shopping.

Table 3. Green marketing definition comparison

Author	**Higlight**
Lievano Pulido et al. (2023)	green marketing is becoming an important topic to deal with the current climate crisis, but it is also fertile enough to merit a literary creation overview.
Moravcikova et al. (2017)	green marketing as a subset of all marketing activities is examined as positive and negative activities and only a limited range of environmental issues.
Majeed et al. (2022)	green marketing tactics to encourage consumers to buy green products.
Machová et al. (2022)	can be defined as a sales process based on the environmental friendliness of a product or service.
Badhwar et al. (2024)	green marketing involves the process of reducing the ecological footprint of products through redesign, sustainable production, and well-coordinated marketing strategies.
Skackauskiene et al. (2023)	green marketing has gained great importance in the modern market and provides a competitive advantage.
Correia et al. (2023)	companies should pay special attention to green communication because it can increase customers' trust in the brand's commitment to the environment and thus positively influence green purchases.
Lopes et al. (2023).	attitude towards buying organic products, behavioral control, social influence, and knowledge about organic products all influence consumers' willingness to buy organic products.
Nozari et al. (2023)	If customers want a sustainable business (and goods or services), they also need sustainable marketing that aims to increase productivity to prevent damage to ecosystems or depletion of natural resources.
Li et al. (2024)	green marketing includes not only the green features of products but also a holistic business process that identifies, anticipates, and meets the needs of consumers and society in harmony with nature for economic sustainability.
Nadanyiova et al. (2020)	Green marketing communication can positively affect the attitude of individual target groups towards the brand.
Bhardwaj et al. (2023)	Since green marketing is primarily concerned with the environment, environmental, social, and economic sustainability is an integral part of sustainable marketing. Innovative thinking in this area is based on user

	needs, involves extensive use of company resources, and starts with users
Nekmahmud et al. (2020)	Green marketing recommends the use of eco-friendly products such as refillable, ozone-friendly, healthy food, phosphate-free, and recyclable products and can be applied in environmentally friendly ways to meet customer needs, wants, and needs to protect the environment and society.
Gheorghe et al. (2023)	green marketing refers to the development and marketing activities of products that are considered environmentally friendly (these products are designed to reduce or improve the negative impact on the environment).

Source: authors development

Shabbir et al. (2020) mentioned that since 2010 green marketing activities have grown rapidly and have gained enough consumer trust to be sustainable and profitable.
García-Salirros et al. (2022) argued that green marketing (GM) aims to meet the needs of the consumer who prefers green products and services.
Summarizing the ideas expressed by the researchers, it can be said that a sales process based on greenness, a product or a service, includes the process of reducing the ecological footprint of products, redesigning, using sustainable production and well-coordinated marketing strategies, has gained great importance in the modern market and provides a competitive advantage, improves organizational performance and increases customer satisfaction, customer behavior indicators, purchase intention and energy consumption.

Internet of Things cases study

Table 4. Internet of Things products and functions, application and availability in Lithuania

Name	Function	Application and availability in Lithuania
 KIA UVO apps **https://owners.kia.com**	Mobile app, thanks to which remote managed by car devices and information collected about the car	Applicable in the car and available in Lithuania
	When Mercedes-Benz introduced the subcompact A-Class sedan to the US market, it used the new model to introduce Mercedes-Benz User Experience (MBUX) technology.	Applicable in the car and available in Lithuania

 Mercedes MBUX system **https://www.jdpower.com**	Depending on the model and its price, MBUX offers different features and functions, but they all have one thing in common: artificial intelligence. Combining digital instruments and a touchscreen infotainment system on a single black screen, MBUX uses artificial intelligence to make the driver's life easier. The technology learns your habits and preferences over time and responds to natural voice requests, similar to smartphone assistants like Siri and smart home assistants like Amazon Alexa.	
 SMART EYE smart recording device https://smarteye.se	The video camera is dedicated use in conjunction with eye tracking system that would be created by the subject image.	Used in cars, researching the driver's gaze behavior in dynamic environment and driving in security systems. Available according to formed companies agreement.
 ZUS intelligent tire pressure gauge **https://www.techguide.com.au/reviews/zus-smart-tyre-safety-monitor-review-drive-safer-save-money-fuel/**	Tire air pressure gauge controlled via mobile app, allows you to monitor the tires condition.	Applicable in cars and not available in Lithuania.

Sinocastel  Sinocastel ELD device T-229L **https://www.sinocastel.com**	Freight transport vehicle gps tracker, Wi-Fi network spreader and basic transport instrument data tracker Controlled via mobile app	In transport the means

Source: authors development

Internet of Things statistical data analysis

As mentioned Statista Research Department (2023). the value of the global Internet of Things (IoT) market in 2024 is predicted will reach about 336 billion US dollars, and in 2030 will grow to more than $621 billion and triple its revenue in ten years

Table 5. Internet of Things (IoT) revenue worldwide from 2024 to 2030 (in billion U.S. dollars)

Characteristic	2024*	2025*	2026*	2027*	2028*	2029*	2030*
Agriculture, Forestry & Fishing	3.7	4.3	5	5.8	6.7	7.7	8.9
Mining & Quarrying	0.8	0.8	0.9	0.9	1	1	1.1
Manufacturing	7.5	8.6	9.8	11.2	12.6	14	15.5
Electricity, Gas, Steam & A/C	23.4	26.1	28.7	31.2	33.6	35.9	37.9
Water Supply & Waste Management	4.2	5	5.8	6.5	7.2	7.9	8.5
Construction	0.9	1	1.1	1.2	1.2	1.3	1.4

Characteristic	2024*	2025*	2026*	2027*	2028*	2029*	2030*
Retail & Wholesale	30.5	32.6	34.4	36	37.6	39	40.5
Transportation & Storage	32.3	35.7	39.2	42.6	46.1	49.7	53.3
Accommodation & Food Service	6.6	7.2	7.7	8.2	8.7	9.1	9.6
Information & Communication	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Finance & Insurance	7.1	8.1	9.1	10.2	11.4	12.6	13.9
Professional, Scientific & Technical	0.4	0.5	0.6	0.6	0.7	0.9	1
Administrative	11.2	13.2	15.4	17.8	20.3	22.8	25.2

Source: https://www.statista.com/statistics/1183471/iot-revenue-worldwide-by-vertical/

As mentioned Statista Research Department (2023). the global indicator Smart Homes by Segment in the smart home market is forecast to grow steadily to a total of 424.5 million units between 2023 and 2028. of consumers (+117.69%). It is estimated that after the ninth consecutive year of growth, this indicator will reach 785.16 million consumers, so in 2028 will reach a new peak. It should be noted that the smart home market indicator "Smart home by segment" has been steadily increasing over the past year.

As mentioned by Statista Research Department (2023), the smart home market consists of the sale of connected devices and services that enable home automation to private end users (B2C). Devices that are directly or indirectly connected through so-called gateways to the Internet are considered. Their main objectives are the control, monitoring and regulation of private household functions.

According Lithuanian Statistical department (2023) in 2022 almost one in five Lithuanians (19%) aged 16-74 used at least one Internet-connected home security system, lighting, energy management system, household appliance or virtual assistant.

Table 6. Individuals who used Internet-connected home systems, home appliances, virtual assistants **(percent)**

	2020	**2022**
Did not use any Internet-connected devices or systems	89.9	80.9
Home appliances such as robot vacuums, fridges, ovens, coffee machines	4.5	12.1
Home alarm systems, smoke detectors, security cameras, door locks, or other security for home	4.9	8.1
Thermostats, utility meters, lighting systems, or other energy management systems	2.5	5.3
A virtual assistant in the form of a smart speaker or of an app, such as Google Assistant, Bixby	1.7	3

Source: https://osp.stat.gov.lt/skaitmenine-ekonomika-ir-visuomene-lietuvoje-2022/skaitmenine-aplinka/daiktu-internetas

According to the Lithuanian Statistical Department (2023) the 25-34 and 35-44 age groups of the population using home systems or household devices connected to the Internet were the most (34 and 30 percent, respectively), while the 65-74 age group had 3 percent of them. One in a hundred Internet users aged 16-74 who did not use the systems or devices said that they had not heard of the existence of such systems or devices (3 percent in 2020), 90 percent. stated that they have no need to use them, 22 percent. - too expensive, 10 percent. - lack of skills, and knowledge.
As stated, Lithuanian Statistical Department (2023) smart watches, fitness bracelets, virtual reality glasses or headsets, security tracking devices, accessories, and internet-connected clothes or shoes in 2022. used by 23 percent. 16-74-year-old people with a wireless Internet connection installed in the car - 8 percent. (12 and 5 percent respectively in 2020). Like other smart devices or systems, smart devices are mainly used by young people.

Conclusions

The results of the study showed that the Internet of Things technologies, it can be concluded that the Internet of Things uses a very diverse and wide spectrum of technologies, which are chosen depending on the area in which the Internet of Things technology will be developed or used. The technologies used could be divided into two types, technologies that provide communication for data transmission and technologies for production of a device that will collect and broadcast information.

References

1. Ali, O.; Ishak, M.K.; Bhatti, M.K.L.; Khan, I.; Kim, K.-I. (2022). A Comprehensive Review of Internet of Things: Technology Stack, Middlewares, and Fog/Edge Computing Interface. *Sensors* 2022, *22*, 995. https://doi.org/10.3390/s22030995
2. Alkhatib, S.; Kecskés, P.; Keller, V. (2023). Green Marketing in the Digital Age: A Systematic Literature Review. Sustainability 2023, 15, 12369. https://doi.org/10.3390/su151612369

3. Al Khatib, I.; Shamayleh, A.; Ndiaye, M. (2024). Healthcare and the Internet of Medical Things: Applications, Trends, Key Challenges, and Proposed Resolutions. *Informatics* 2024, *11*, 47. https://doi.org/10.3390/informatics11030047
4. Alzahrani, A.; Asghar, M.Z. (2023). Intelligent Risk Prediction System in IoT-Based Supply Chain Management in Logistics Sector. *Electronics* 2023, *12*, 2760. https://doi.org/10.3390/electronics12132760
5. Amaya Rivas, A.; Liao, Y.-K.; Vu, M.-Q.; Hung, C.-S. (2022). Toward a Comprehensive Model of Green Marketing and Innovative Green Adoption: Application of a Stimulus-Organism-Response Model. Sustainability 2022, 14, 3288. https://doi.org/10.3390/su14063288
6. Badhwar, A.; Islam, S.; Tan, C.S.L.; Panwar, T.; Wigley, S.; Nayak, R. (2024). Unraveling Green Marketing and Greenwashing: A Systematic Review in the Context of the Fashion and Textiles Industry. *Sustainability* 2024, *16*, 2738. https://doi.org/10.3390/su16072738
7. Baužytė, A. (2020). Ekologiškumo vaidmuo šiuolaikiniame marketinge. Lietuvos aukštųjų mokyklų vadybos ir ekonomikos jaunųjų mokslininkų Konferencijų darbai 2020 / 23, 32-36, https://doi.org/10.7220/2538-6778.2020.23
8. Bhardwaj, S.; Nair, K.; Tariq, M.U.; Ahmad, A.; Chitnis, A. (2023). The State of Research in Green Marketing: A Bibliometric Review from 2005 to 2022. *Sustainability* 2023, *15*, 2988. https://doi.org/10.3390/su15042988
9. Brochado, Â.F.; Rocha, E.M.; Costa, D. (2024). A Modular IoT-Based Architecture for Logistics Service Performance Assessment and Real-Time Scheduling towards a Synchromodal Transport System. *Sustainability* 2024, *16*, 742. https://doi.org/10.3390/su16020742
10. Cano-Suñén, E.; Martínez, I.; Fernández, Á.; Zalba, B.; Casas, R. (2023). Internet of Things (IoT) in Buildings: A Learning Factory. *Sustainability* 2023, *15*, 12219. https://doi.org/10.3390/su151612219
11. Chataut, R.; Phoummalayvane, A.; Akl, R. (2023). Unleashing the Power of IoT: A Comprehensive Review of IoT Applications and Future Prospects in Healthcare, Agriculture, Smart Homes, Smart Cities, and Industry 4.0. Sensors 2023, 23, 7194. https://doi.org/10.3390/s23167194
12. Chen, J.; Xu, S.; Liu, K.; Yao, S.; Luo, X.; Wu, H. (2022). Intelligent Transportation Logistics Optimal Warehouse Location Method Based on Internet of Things and Blockchain Technology. Sensors 2022, 22, 1544. https://doi.org/10.3390/s22041544
13. Correia, E.; Sousa, S.; Viseu, C.; Larguinho, M. (2023). Analysing the Influence of Green Marketing Communication in Consumers' Green Purchase Behaviour. *Int. J. Environ. Res. Public Health* 2023, *20*, 1356. https://doi.org/10.3390/ijerph20021356
14. Dhanaraju, M.; Chenniappan, P.; Ramalingam, K.; Pazhanivelan, S.; Kaliaperumal, R. (2022). Smart Farming: Internet of Things (IoT)-Based Sustainable Agriculture. *Agriculture* 2022, *12*, 1745. https://doi.org/10.3390/agriculture12101745
15. Esmaelnezhad, D.; Lagzi, M.D.; Antucheviciene, J.; Hashemi, S.S.; Khorshidi, S. (2023). Evaluation of Green Marketing Strategies by Considering Sustainability Criteria. Sustainability 2023, 15, 7874. https://doi.org/10.3390/su15107874
16. European Center for Quality Ltd Bulgarija (2016). Žaliasis Tinklinis Marketingas. 2015-1-IT02-KA204-014787.

17. Farhan, L.; Hameed, R.S.; Ahmed, A.S.; Fadel, A.H.; Gheth, W.; Alzubaidi, L.; Fadhel, M.A.; Al-Amidie, M. (2021). Energy Efficiency for Green Internet of Things (IoT) Networks: A Survey. *Network* 2021, *1*, 279-314. https://doi.org/10.3390/network1030017
18. Farias da Costa, V.C.; Oliveira, L.; de Souza, J. (2021). Internet of Everything (IoE) Taxonomies: A Survey and a Novel Knowledge-Based Taxonomy. *Sensors* 2021, *21*, 568. https://doi.org/10.3390/s21020568
19. García-Salirrosas, E.E.; Rondon-Eusebio, R.F. (2022). Green Marketing Practices Related to Key Variables of Consumer Purchasing Behavior. *Sustainability* 2022, *14*, 8499. https://doi.org/10.3390/su14148499
20. Gheorghe, G.; Tudorache, P.; Roşca, I.M. (2023). The Contribution of Green Marketing in the Development of a Sustainable Destination through Advanced Clustering Methods. *Sustainability* 2023, *15*, 13691. https://doi.org/10.3390/su151813691
21. Ghashim, I., A., Arshad, M. (2023). Internet of Things (IoT)-Based Teaching and Learning: Modern Trends and Open Challenges. Sustainability. 2023; 15(21):15656. https://doi.org/10.3390/su152115656
22. Govindan, K., Cheng, T.C.E., Mishra,N., Shukla,N. (2018). Big data analytics and application for logistics and supply chain management. Transp. Res. Part E Logist. Transp. Rev. 114, 343–349 (2018).
23. Hamdan, S.; Ayyash, M.; Almajali, S. (2020). Edge-Computing Architectures for Internet of Things Applications: A Survey. *Sensors* 2020, *20*, 6441. https://doi.org/10.3390/s20226441
24. Jarašūnienė, A.; Čižiūnienė, K.; Čereška, A. (2023). Research on Impact of IoT on Warehouse Management. *Sensors* 2023, *23*, 2213. https://doi.org/10.3390/s23042213
25. Katal,A., Wazid,M., Goudar, R., H. (2013). Big data: issues, challenges, tools and good practices. IEEE 404–409.
26. Kaur, B.; Gangwar, V.P.; Dash, G. (2022). Green Marketing Strategies, Environmental Attitude, and Green Buying Intention: A Multi-Group Analysis in an Emerging Economy Context. Sustainability 2022, 14, 6107. https://doi.org/10.3390/su14106107
27. Kaur, H., Singh,S., P. (2016). Heuristic modeling for sustainable procurement and logistics in a supply chain using big data. Comput. Oper. Res. 98, 301–321 (2016)
28. Khan, Y.; Suud, M.B.M.; Alam, M.M.; Ahmad, S.F.; Ahmad, A.Y.A.B.; Khan, N. (2023). Application of Internet of Things (IoT) in Sustainable Supply Chain Management. *Sustainability* 2023, *15*, 694. https://doi.org/10.3390/su15010694
29. Klumpp, M. (2016). To Green or Not to Green: A Political, Economic and Social Analysis for the Past Failure of Green Logistics. Sustainability 2016, 8, 441. https://doi.org/10.3390/su8050441
30. Kiyak, D.; Grigoliene, R. (2023). Analysis of the Conceptual Frameworks of Green Marketing. *Sustainability* 2023, *15*, 15630. https://doi.org/10.3390/su152115630
31. K.; Straka, M. (2024). The Use of the Internet of Things in the Distribution Logistics of Consumables. *Appl. Sci.* 2024, *14*, 3263. https://doi.org/10.3390/app14083263
32. Li, W.; Zhang, J.; Zhu, H.; Hao, T.; Mei, L.; Su, Y. (2024). Green Marketing and the Path to Realizing Local Sustainable Development—Joint Dynamic Analysis of Data Envelopment

Analysis (DEA) and Fuzzy Set Qualitative Comparative Analysis (fsQCA) Based on China's Provincial Panel Data. *Sustainability* 2024, *16*, 4644. https://doi.org/10.3390/su16114644

33. Lievano Pulido, Y.P.; Ramon-Jeronimo, M.A. (2023). Green Marketing: A Bibliographic Perspective. *Sustainability* 2023, *15*, 16674. https://doi.org/10.3390/su152416674
34. Lithuanian Statistical department (2023). Digital Economy and Society in Lithuania, https://osp.stat.gov.lt/skaitmenine-ekonomika-ir-visuomene-lietuvoje-2022/skaitmenine-aplinka/daiktu-internetas
35. Lombardi, M.; Pascale, F.; Santaniello, D. (2021). Internet of Things: A General Overview between Architectures, Protocols and Applications. *Information* 2021, *12*, 87. https://doi.org/10.3390/info12020087
36. Long, L. (2022). Research on status information monitoring of power equipment based on Internet of Things. Energy Reports, 8, 281-286.
37. Lopes, J.M.; Gomes, S.; Trancoso, T. (2023). The Dark Side of Green Marketing: How Greenwashing Affects Circular Consumption? *Sustainability* 2023, *15*, 11649. https://doi.org/10.3390/su151511649
38. Machová, R.; Ambrus, R.; Zsigmond, T.; Bakó, F. (2022). The Impact of Green Marketing on Consumer Behavior in the Market of Palm Oil Products. *Sustainability* 2022, *14*, 1364. https://doi.org/10.3390/su14031364
39. Majeed, M.U.; Aslam, S.; Murtaza, S.A.; Attila, S.; Molnár, E. (2022). Green Marketing Approaches and Their Impact on Green Purchase Intentions: Mediating Role of Green Brand Image and Consumer Beliefs towards the Environment. *Sustainability* 2022, *14*, 11703. https://doi.org/10.3390/su141811703
40. Mansour, Klumpp, M. (2016). To Green or Not to Green: A Political, Economic and Social Analysis for the Past Failure of Green Logistics. Sustainability 2016, 8, 441. https://doi.org/10.3390/su8050441M
41. Mashat, R.M.; Abourokbah, S.H.; Salam, M.A. (2024). Impact of Internet of Things Adoption on Organizational Performance: A Mediating Analysis of Supply Chain Integration, Performance, and Competitive Advantage. *Sustainability* 2024, *16*, 2250. https://doi.org/10.3390/su16062250
42. Mashayekhy, Y.; Babaei, A.; Yuan, X.-M.; Xue, A. (2022). Impact of Internet of Things (IoT) on Inventory Management: A Literature Survey. *Logistics* 2022, *6*, 33. https://doi.org/10.3390/logistics6020033
43. Mansour M, Gamal A, Ahmed AI, Said LA, Elbaz A, Herencsar N, Soltan A. . (2023). Internet of Things: A Comprehensive Overview on Protocols, Architectures, Technologies, Simulation Tools, and Future Directions. Energies. 2023; 16(8):3465. https://doi.org/10.3390/en16083465
44. Mejjaouli, S. (2022). Internet of Things based Decision Support System for Green Logistics. *Sustainability* 2022, *14*, 14756. https://doi.org/10.3390/su142214756
45. Mo, D.Y.; Ma, C.Y.T.; Ho, D.C.K.; Wang, Y. (2022). Design of a Reverse Logistics System with Internet of Things for Service Parts Management. *Sustainability* 2022, *14*, 12013. https://doi.org/10.3390/su141912013

46. Moravcikova, D.; Krizanova, A.; Kliestikova, J.; Rypakova, M. (2017). Green Marketing as the Source of the Competitive Advantage of the Business. *Sustainability* 2017, *9*, 2218. https://doi.org/10.3390/su9122218
47. Mostafa, N.; Hamdy, W.; Alawady, H. (2019). Impacts of Internet of Things on Supply Chains: A Framework for Warehousing. *Soc. Sci.* 2019, *8*, 84. https://doi.org/10.3390/socsci8030084
48. Musa, A.A.; Malami, S.I.; Alanazi, F.; Ounaies, W.; Alshammari, M.; Haruna, S.I. (2023). Sustainable Traffic Management for Smart Cities Using Internet-of-Things-Oriented Intelligent Transportation Systems (ITS): Challenges and Recommendations. Sustainability 2023, 15, 9859. https://doi.org/10.3390/su15139859
49. Nadanyiova, M.; Gajanova, L.; Majerova, J. (2020).Green Marketing as a Part of the Socially Responsible Brand's Communication from the Aspect of Generational Stratification. *Sustainability* 2020, *12*, 7118. https://doi.org/10.3390/su12177118
50. Nekmahmud, M.; Fekete-Farkas, M. (2020). Why Not Green Marketing? Determinates of Consumers' Intention to Green Purchase Decision in a New Developing Nation. *Sustainability* 2020, *12*, 7880. https://doi.org/10.3390/su12197880
51. Ntafloukas, K.; McCrum, D.P.; Pasquale, L. (2023). A Cyber-Physical Risk Assessment Approach for Internet of Things Enabled Transportation Infrastructure. Appl. Sci. 2022, 12, 9241. https://doi.org/10.3390/app12189241
52. Nozari, H.; Szmelter-Jarosz, A.; Ghahremani-Nahr, J. (2023). The Ideas of Sustainable and Green Marketing Based on the Internet of Everything— The Case of the Dairy Industry. Future Internet 2021, 13, 266. https:// doi.org/10.3390/fi13100266
53. Oladimeji, D.; Gupta, K.; Kose, N.A.; Gundogan, K.; Ge, L.; Liang, F. (2023). Smart Transportation: An Overview of Technologies and Applications. *Sensors* 2023, *23*, 3880. https://doi.org/10.3390/s23083880
54. Paolone, G.; Iachetti, D.; Paesani, R.; Pilotti, F.; Marinelli, M.; Di Felice, P. (2022).A Holistic Overview of the Internet of Things Ecosystem. *IoT* 2022, *3*, 398-434. https://doi.org/10.3390/iot3040022
55. Panavė, J., Burinskienė, A. (2023). Daiktų interneto technologijų taikymas logistikoje. 26-osios Lietuvos jaunųjų mokslininkų konferencijos „Mokslas – Lietuvos ateitis" teminė konferencija Proceedings of the 26th Conference for Junior Researchers "Science – Future of Lithuania" EKONOMIKA IR VADYBA / ECONOMICS AND MANAGEMENT.
56. Pancić, M.; Serdarušić, H.; Ćućić, D. (2023). Green Marketing and Repurchase Intention: Stewardship of Green Advertisement, Brand Awareness, Brand Equity, Green Innovativeness, and Brand Innovativeness. *Sustainability* 2023, *15*, 12534. https://doi.org/10.3390/su151612534
57. Paužuolienė, J.. Kaveckė, I. (2022). Žaliosios logistikos taikymo svarba: vartotojų nuomonės tyrimas. Regional Formation and Development Studies, No. 1 (36), 1-8.
58. Plaza-Úbeda, J.A.; Abad-Segura, E.; de Burgos-Jiménez, J.; Boteva-Asenova, A.; Belmonte-Ureña, L.J. (2021). Trends and New Challenges in the Green Supply Chain: The Reverse Logistics. Sustainability 2021, 13, 331. https://doi.org/10.3390/su13010331
59. Prajapati, D.; Chan, F.T.S.; Chelladurai, H.; Lakshay, L.; Pratap, S. (2022). An Internet of Things Embedded Sustainable Supply Chain Management of B2B E-Commerce. *Sustainability* 2022, *14*, 5066. https://doi.org/10.3390/su14095066

60. Rashvand, N.; Hosseini, S.S.; Azarbayjani, M.; Tabkhi, H. (2024). Real-Time Bus Departure Prediction Using Neural Networks for Smart IoT Public Bus Transit. *IoT* 2024, *5*, 650-665. https://doi.org/10.3390/iot5040029
61. Rejeb, A.; Rejeb, K.; Zrelli, I. (2024). Analyzing Barriers to Internet of Things (IoT) Adoption in Humanitarian Logistics: An ISM–DEMATEL Approach. *Logistics* 2024, *8*, 38. https://doi.org/10.3390/logistics8020038
62. Savukynas, R., Marcinkevičius, V. (2017). Daiktų interneto objektų identifikavimo metodų palyginimas / Informacijos mokslai. Vilnius : Vilniaus universiteto leidykla.. 78, p. 66-82, DOI: https://doi.org/10.15388/Im.2017.78.10835
63. Singh, S., K., Roy, S. (2020). Internet of Things (IoT) Based Green Logistics Operations for Sustainable Development in the Indian Context. Nanoelectronics, Circuits and Communication Systems (pp.301-313), DOI:10.1007/978-981-15-2854-5_27
64. Shabbir, M.S.; Bait Ali Sulaiman, M.A.; Hasan Al-Kumaim, N.; Mahmood, A.; Abbas, M. (2020). Green Marketing Approaches and Their Impact on Consumer Behavior towards the Environment—A Study from the UAE. Sustainability 2020, 12, 8977. https://doi.org/10.3390/su12218977
65. Skackauskiene, I.; Vilkaite-Vaitone, N. (2023). Green Marketing and Customers' Purchasing Behavior: A Systematic Literature Review for Future Research Agenda. Energies 2023, 16, 456. https://doi.org/ 10.3390/en16010456
66. Statista Research Department (2023). Number of users of smart homes worldwide 2019-2028. https://www.statista.com/forecasts/887613/number-of-smart-homes-in-the-smart-home-market-in-the-world
67. Strandhagen, J.W.; Alfnes, E.; Strandhagen, J.O.; Vallandingham, L.R. (2017). The fit of Industry 4.0 applications in manufacturing logistics: A multiple case study. Adv. Manuf. 2017, 5, 344–358.
68. Šulyová, D.; Koman, G. (2020). The Significance of IoT Technology in Improving Logistical Processes and Enhancing Competitiveness: A Case Study on the World's and Slovakia's Wood-Processing Enterprises. *Sustainability* 2020, *12*, 7804. https://doi.org/10.3390/su12187804
69. Twahirwa, E.; Rwigema, J.; Datta, R. (2022). Design and Deployment of Vehicular Internet of Things for Smart City Applications. Sustainability 2022, 14, 176. https://doi.org/10.3390/su14010176
70. Vilkaitė-Vaitonė, N., Skačkauskienė, I. (2022). Žaliasis marketingas Lietuvoje: kritinis vertinimas ir plėtros galimybės : mokslo studija. Vilnius : Ciklonas, 2022 130 p. Laisvai prieinamas internete / Unrestricted online access. ISBN: 9786098122985 ; eISBN: 9786098122992.
71. Wu, Ah., Lin, S. (2016). The effect of green marketing strategy on business performance: a study of organic farms in Taiwan. Total Quality Management, 27(2), 141-156.
72. Yang, S.; Chai, J. (2022). The Influence of Enterprises' Green Marketing Behavior on Consumers' Green Consumption Intention—Mediating Role and Moderating Role. Sustainability 2022, 14, 15478. https://doi.org/10.3390/su142215478

73. Zantalis, F.; Koulouras, G.; Karabetsos, S.; Kandris, D. (2019). A Review of Machine Learning and IoT in Smart Transportation. *Future Internet* 2019, *11*, 94. https://doi.org/10.3390/fi11040094
74. Zeeshan, K.; Hämäläinen, T.; Neittaanmäki, P. (2022). Internet of Things for Sustainable Smart Education: An Overview. *Sustainability* 2022, *14*, 4293. https://doi.org/10.3390/su14074293
75. https://eteismai.lt/straipsniai/kita/organiska-ir-tvaru-bet-ar-legalu-zalioji-reklama-ir-ekologiskumo-teiginiu-direktyva
76. https://www.statista.com/statistics/1183471/iot-revenue-worldwide-by-vertical/

Chapter 3 Smart machines and artificial intelligence

SMART MACHINES IN FINANCE: HARNESSING AI FOR A MORE RESILIENT AND EFFICIENT SECTOR

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Abstract

In this research, the authors analyze how artificial intelligence is changing the financial sector by making it more agile, flexible, and resilient. With financial institutions increasingly turning towards artificial intelligence and predictive analysis such as machine learning, automated systems and complex market dynamics, financial institutions are not only improving on routine process, but also developing more adaptive and responsive frameworks. In this study, the authors investigate the ways that artificial intelligence is being incorporated to improve risk management, automate trading, detect fraud, and allocate customer experience, thereby making the financial ecosystem more efficient and resilient.

The research highlights the great capacity that artificial intelligence can contribute in reducing financial risks, improving decision making, and increasing operational continuity especially in the volatile or crisis states of the economy. It also investigates the ethical and governance problems associated with the pervasive use of artificial intelligence, such as algorithmic bias, transparency, and accountability. The research then addresses these concerns and demonstrates that robust regulatory frameworks and ethical guidelines are urgently needed to support the safe deployment of artificial intelligence in high stakes environments.

Finally, the study proposes econometric model to measure the impact of artificial intelligence on financial performance using profitability, risk reduction and operational efficiency as key metrics on a sample of leading financial institutions. It does this by providing a data driven approach to understand artificial intelligence returns on artificial intelligence investments and insight into financial outcomes from artificial intelligence adoption.

Finally, emerging technologies like quantum computing and artificial intelligence enabled blockchain are talked about. The findings emphasize how important it is to balance technological innovation with ethical considerations and urge further research concerning the global dimensions of artificial

intelligence, including their implications on financial inclusion and the economy of developing countries.

Keywords: *artificial intelligence, financial resilience, operational efficiency, risk management, machine learning, ethical governance, financial inclusion.*

Introduction

Artificial Intelligence (AI) has become a powerful weapon in tackling the multifaceted difficulties with which the contemporary financial sector work (Gupta, 2023). With rapid technological advancement and increasing evolution in the global financial markets, traditional means of managing the market seem to fail to keep up. However, these complexities are best managed through the AI that builds on data analysis, pattern recognition, predictive modelling to name a few. Through these technologies, financial institutions can ingest significant amounts of information at precisely the right speed and with unparalleled accuracy in order to make decisions fast in volatile markets (Haenlein, Kaplan, 2019).

Risk management, especially about market fluctuations and systemic risks, is considered one of the most urgent problems in the financial sphere. Models driven by artificial intelligence are especially great at taking in historical data, looking for trends, and producing forecasts so institutions can have an idea of what to expect and prepare for a possible disruption (Garg, Hosen, 2020). Like fraud detection and prevention, AI has become very important in this area too. Machine learning algorithms can detect anomalies via machine learning algorithms, this will flag potentially fraudulent activities in real time and protect assets (Vishwanath, Bhat, 2020).

Moreover, the financial sector is under stress for continual improvement in operational efficiency and lowering costs. RPA and NLP are routinely deployed AI technologies that help reduce labor costs, execute routine tasks automatically, and optimize your resource allocation whilst offering better customer experiences. These advancements both reduce operations burdens and free up human capital for strategic projects (Smith, Williams, 2021).

Regulatory compliance is also addressed by the adoption of AI and has been a growing challenge everywhere in the world as the governments increase controls on the activities of the companies (Binns, Hu, 2021). In addition to saving on compliance risks, AI systems can monitor transactions, ensure regulatory compliance and provide audit trails efficiently, significantly reducing the risk of noncompliance. In doing so, AI is indispensable in helping the financial sector transition from one that is less robust and efficient to the one that is more capable, resilient and adaptive.

The research seeks to understand the ability of artificial intelligence to be transformative in the financial sector, specifically its capacity to increase resilience and efficiency. The study investigates how AI powered technologies could tackle the extreme challenges, risk, and operational optimization to find how these innovations help build a more robust financial ecosystem. It also explores factors in AI that could help improve decision making process, streamlined operations and help for sustainability in the context of economic volatility. The research offers through this comprehensive analysis, insights into the changing dynamics of finance, and the crucial interface between technology and financial resiliency.

Evolution of AI in finance

Through all of this a series of milestones have been set for AI and AI based technologies in finance. AI in finance dates back to the early 1960s when simple automation was used to automate some of a banking system's transactions and manage data. As the capability for computational power and data storage improvements grew, these rudimentary tools prepared the way for more sophisticated applications (Haenlein, Kaplan, 2019).

In the 1980s and 1990s machine learning and neural networks started to impact financial practices. Machine learning models with AI power were created to learn market trends to optimize portfolio management strategies. This era saw the birth of the algorithmic trading, which has completely changed, in terms of speed and efficiency, how financial transactions are being done trading based on data driven insights, and conducting trades within a span of milliseconds (Singh, Sharma, 2022). These developments also transformed the pattern of operational efficiency but also the characteristics of global financial market.

During the early 2000s, there was a more highly specialized application of AI, in the areas of risk management and fraud detection. With the rise of digital banking and increasing complexity in financial transactions, machine learning algorithms were adapted to spot anomaly in transaction patterns and prevent real time fraud. At the same time, natural language processing contributed to AI customer-facing experience such as chatbots and improve clients' interactions and service (Garg, Hosen, 2020).

During these years, deep learning and big data analytics has further accelerated the role of AI in finance. New technologies, including predictive analytics, sentiment analysis and blockchain-enabled AI, now provide new dimensions to decision making and transparency. However, artificial intelligence continues to be a stellar marker of progress in the financial landscape, and these innovations continue to redefine the financial landscape. It goes without saying that AI has contributed significantly to the current financial eco system by automating routine tasks and the ability to use it to executing highly sophisticated financial strategies (Chauhan, Chandra, 2019).

The process has been transforming the financial sector and each of the milestones is a step further in innovation and capability brought about by advancements in artificial intelligence (Lauer, Mlachila, 2021). A detailed chronicle of these breakthroughs shows the sector adapting to technological progress from the early integration of algorithmic trading systems to latest convergence of AI and blockchain. One of the first and most far reaching applications to date has been in algorithmic trading, which has changed market operations by automating trade execution at blinding speed and accuracy (Brown, Jackson, 2022). With this development, more sophisticated applications, such as fraud detection systems and robo-advisors, are added that are entirely necessary in the ever-evolving world of security and accessibility in finance (Haenlein, Kaplan, 2019).

Recently, the integration of AI and blockchain technology has brought new degrees of transparency and security to the industry by integrating the latest solutions to the technologies in use. There is a strategic response behind each milestone, partially each utilized technology for increasing efficiency, accessibility and resiliency of the sector.

Table 1 delineates the milestones laid out by artificial intelligence in drawing up the map for the modern financial architecture. Each breakthrough represents a large step toward meeting changing

sector needs including more efficient operations, greater market transparency, and increased security and customer engagement. High speed, data driven decision making was set in place by algorithmic trading, fraud detection systems and robo-advisors brought AI's influence from safeguarding assets to democratizing financial services.

Table 1. Major milestones in AI applications in finance

No.	Year/Period	Breakthrough	Description	Impact
1.	1980s-1990s	Algorithmic trading	Introduction of AI-driven models to automate trade execution based on pre-set criteria like price, timing, or volume.	Revolutionized trading by increasing speed, reducing costs, and improving market efficiency.
2.	Early 2000s	Fraud detection systems	Deployment of machine learning algorithms to analyze transaction patterns and identify anomalies indicative of fraud.	Enhanced financial security by enabling real-time detection and prevention of fraudulent activities.
3.	2010s	Robo-advisors	AI-powered platforms providing automated, algorithm-driven financial planning and investment management services.	Democratized investment by offering cost-effective and accessible financial advice to a wider audience.
4.	2015-Present	Sentiment analysis tools	Use of AI to analyze news, social media, and other text sources for market sentiment insights.	Improved investment strategies through real-time sentiment-based predictions.
5.	2020s	Blockchain-integrated AI	Combining AI with blockchain to enhance transparency, security, and efficiency in financial transactions.	Enabled innovations in decentralized finance (DeFi) and improved fraud resistance.

Source: authors development using data from World Bank (2023), Research and Markets (2022), International Monetary Fund (2021), Financial Stability Board (2020)

The edge of financial sector boundaries is ever-shifting as the sector takes on sentiment analysis and blockchain fortified AI as preferred innovators and flexible change agents. This doesn't just show the usefulness of AI to tackle multiple problems but also betrays its ability to facilitate future changes. By themselves or in combination, these accomplishments represent a quantified assertion of AI's enduring presence in finance, a transformer of risk and progress in an increasingly challenging, multifaceted global economy (Gartner, 2023).

Yet AI found early adoption in the financial sector, with numerous challenges, first and foremost due to a lack of technological infrastructures, skepticism of stakeholders, and regulatory uncertainties. The lack of computational power and data storage capabilities necessary to support AI driven applications led to one significant hurdle. Although AI tools were not very effective or scalable at the early financial system, this was because early financial systems were not built to handle the large amount of data required for machine learning models. Furthermore, financial institutions were challenged in integrating AI technologies into their existing legacy systems thereby causing inefficiency and compatibility issues (Chauhan, Chandra, 2019).

A large challenge was finding how to overcome the skepticism and resistance of stakeholders, including executives and employees, who were not sure if AI was, as Betty stated, reliable and if it could do what it promised. Fear of job displacement only spurred further resistance, though this was exacerbated as automation started to usurp mundane tasks. The question was asked back then: Could these errors be made, if AI was being used on how to assess risk and detect fraud, for instance, and could the resulting outcomes be deemed accurate and trustworthy?

There were also major obstacles owing to regulatory and ethical uncertainties. The introduction of AI brought questions regarding data privacy, algorithmic transparency and accountability in the decision making. And because these complexities were so unprecedented, regulators were often unprepared to address them, leaving opaque guidelines for how to do with AI what we've always done with law. That uncertainty stalled widespread adoption by financial institutions because of hesitation (Lauer, Mlachila, 2021).

Targeted solutions were developed to meet these challenges over time (Harrison, Thomas, 2021). The technological restrictions of AI were overcome through advances in computational power combined with cloud storage and big data analytics, allowing the technology to process and analyze large datasets with ease. To be able to integrate such things in the future, financial institutions started investing in modernizing their infrastructure to make it more accommodating to AI systems and, by extension, make them work with the existing operations smoothly (Gupta, 2023).

To overcome skepticism, institutions focused on educating stakeholders about AI's benefits, showcasing successful pilot projects, and emphasizing the collaborative potential of AI as a tool to augment human expertise rather than replace it. This approach helped build trust and acceptance among employees and executives alike (Robinson, Lee, 2019).

On the regulatory front, collaborations between financial institutions, policymakers, and technology experts led to the development of clearer guidelines and ethical standards for AI usage. These frameworks emphasized transparency, fairness, and accountability, reducing uncertainty and encouraging responsible AI adoption. Collectively, these resolutions paved the way for the successful integration of AI into the financial sector, transforming it into a more resilient and innovative industry.

AI applications in finance

In the financial sector, we've seen the integration of AI meant that also the subfields started to make significant advancements in key different subjects where they tackle some problems and open up new opportunities. Risk assessment and credit scoring is one of the most critical areas covered by AI driven models which involve scanning a huge data set to determine the creditworthiness of a customer and

giving credit scores with more accuracy and efficiency than conventional methods (Garg, Hosen, 2020). Machine learning algorithms are used in theses system to find patterns and predicts which borrower will do what, and thus financial institutions can make such animation while they see that they will not be into default risk (Kotsiantis, Papanikolopoulos, 2020). Similarly, these models incorporate nontraditional data sources, online activity and alternative financial behaviors, while increasing financial inclusion and helping the under banked.

One another transformation application for AI in finance is Automated trading systems. Automated trading processes large amounts of market information without error and emotion, resulting in greater consistent and more profitable outcomes. In this domain, AI not only increased market liquidity, but has also allowed for the creation of such complex strategies as high frequency trading or arbitrage that are unattainable at scale (Haenlein, Kaplan, 2019).

Yet another very important are the fraud detection and prevention subfield, where AI had made great strides. In real time, machine learning algorithms monitor transactional data and indicate whether these activities are anomalies - and potentially fraudulent ones (Choi, Lee, 2021). Unlike typical rule-based systems, however, AI models continue to evolve, learning directly from the data, getting better and better over time. In particular, this capability is critical when one is combating growing advanced cyber threats and financial crimes, protecting both institutions and their own customers from potentially significant losses (Harrison, Thomas, 2021).

In addition to financial applications, AI has increasingly focused on enhancing the customer experience as AI driven chatbots enhance the customer experience (Liu, Zhang, 2022). These are intelligent systems that respond to customer queries, solve issues and give them personalized financial advice. Using natural language processing and machine learning, chatbots present human like interaction reducing the response time and cost of operation. On top of this, their ability to run continuously helps guarantee reliable and obtainable consumer service that helps enhance client contentment and loyalty (Robinson, Lee, 2019).

Together, these subfields show how AI is capable of solving different problems in the field of finance. In the field of finance, AI seeks to adapt operations, keep them secure and engage more with customers. While there’s been both transformative success stories and major challenges when applying AI to the financial sector, there’s no doubt that a domain is developing. Table 2 presents case studies of how AI is impacting the future of finance, featuring insights into both the advantages and the risks AI brings to the table. AI has found tremendous potential in being used by financial giants such as JPMorgan Chase and MasterCard to optimize operations, enhance security and elevate customer experiences. Other important lessons from the failures and controversies in implementing AI - like obesity and chipotle in Toyota's electronics, algorithmic trading errors at Goldman Sachs, allegations of bias in the Wells Fargo credit scoring systems - help illustrate these complexities at the same time. As critical touchpoints, these case studies provide important insights into the opportunities and risks in putting AI into financial systems.

The case studies presented highlight the transformative potential of artificial intelligence in the financial sector, while also underscoring the importance of careful implementation, monitoring, and ethical consideration. Successes like JPMorgan Chase's COiN and MasterCard’s AI-driven fraud detection demonstrate how AI can streamline operations, enhance security, and improve customer satisfaction. However, the failures and controversies, such as the trading algorithm malfunction at

Goldman Sachs and AI bias in credit scoring at Wells Fargo, serve as cautionary tales, reminding financial institutions of the risks involved in deploying AI without adequate safeguards. These examples emphasize the need for comprehensive testing, transparency, and accountability in AI applications. As AI continues to evolve, these case studies offer crucial lessons that guide the responsible integration of AI in the financial sector, ensuring that its benefits are maximized while mitigating potential pitfalls.

Table 2. Case studies in AI applications in finance

No.	Institution	Case study	Details	Lessons learned
1.	JPMorgan Chase	Success: COiN (contract intelligence)	Utilized AI to analyze and extract data from legal documents, completing tasks in seconds that previously took thousands of hours.	Demonstrated AI's potential to streamline labor-intensive processes and reduce costs.
2.	MasterCard	Success: AI-powered fraud detection	Deployed an AI-based system to monitor transactions in real-time, significantly reducing fraudulent activities while maintaining transaction speed.	Highlighted the importance of real-time analytics in enhancing security and trust.
3.	Goldman Sachs	Failure: algorithmic trading error	Experienced a trading algorithm malfunction, leading to significant financial losses and reputational damage.	Stressed the need for rigorous testing and monitoring of AI systems before deployment.
4.	Wells Fargo	Controversy: AI bias in credit scoring	Faced allegations of bias in an AI-powered credit scoring system, which reportedly disadvantaged certain demographics.	Emphasized the necessity of ensuring fairness and transparency in AI algorithms.

Source: authors development using data from World Bank (2023), Research and Markets (2022), International Monetary Fund (2021), Financial Stability Board (2020)

Econometric modeling: measuring AI's impact

This research quantifies the impact of AI on key financial performance metrics (profitability, risk reduction, and operational efficiency). The importance of understanding how AI technologies have integrated into the finance sector is becoming more and more crucial, as technologies are steadily starting to enforce core aspects of financial performance. From a profitability perspective, automation powered by AI has the ability to simplify decision making and consequently lend itself to more profit generating outcomes by better optimizing trading strategies, more sophisticated asset managing, and

seamless operation which may result in reduced operational costs. Risk reduction through AI is very important as machine learning algorithms can onboard risk in real time so that the institutions can proactively come with measures in cases like fraud detection, credit scoring and also in case of market volatility. Moreover, AI can also contribute to efficiency of operation by automating routine tasks, optimizing resource allocation and improvement of customer's service with AI powered chatbots, which streamlines operations and reduces operational overhead (Chauhan, Chandra, 2019).

This econometric model calculates the impact of AI investments on major financial performance measures of the financial sector. This model analyzes the relationship between AI spending, market conditions and regulatory change, to learn empirical insights about the impact of AI adoption on profitability, operational efficiency and risk management. It is in the background of rapid technological development and changing regulations that financial industry is increasingly exploring AI to improve its operation. The precise impact that AI can have on financial performance, is however, complex and requires analytical rigor. To fill that gap, a model is generated here using financial performance indicators, like Return on Equity (ROE) and cost to income ratios as the dependent variables and AI Investments, Market Conditions, and Regulatory Changes as the key independent variables.

The proposed econometric model aims to analyze the impact of AI investments on financial performance indicators, with a focus on profitability, operational efficiency, and risk reduction. The model is designed as follows:

$$Y = \beta_0 + \beta_1 \cdot AI\ Investments + \beta_2 \cdot Market\ conditions + \beta_3 \cdot Regulatory\ changes + \epsilon \qquad (1)$$

Where

- Y -financial performance indicators (e.g., ROE, cost-to-income ratio).
- *AI investments* - annual expenditure on AI tools.
- *Market conditions* - index proxies like volatility index (VIX).
- *Regulatory changes* - dummy variable (1 for years with major AI-related financial regulations, 0 otherwise).

The dependent variable (Y) represents financial performance indicators, which could include metrics like ROE, cost-to-income ratio, or other relevant indicators of financial performance. These metrics provide insight into how well an institution is performing in terms of profitability, cost efficiency, and overall financial health.

AI Investments - this variable captures the annual expenditure of a financial institution on AI tools, technologies, and related services. The amount of money spent on AI investments can be seen as a proxy for the level of commitment to AI integration, with higher spending likely indicating a more advanced and extensive use of AI within the organization.

Market conditions - this variable accounts for the broader economic and market environment in which the institution operates. Proxies like the VIX can be used to capture market volatility, which impacts financial performance. Increased volatility often heightens the risks associated with investments, which, in turn, can influence profitability and operational decisions.

Regulatory changes - this dummy variable takes the value of 1 for years in which there were major regulatory changes related to AI adoption in the financial sector, and 0 for other years. It captures the

impact of external regulatory forces that may either enable or constrain AI implementation in financial institutions. Regulatory changes may have significant implications for how AI is deployed, especially in terms of compliance, transparency, and risk management.

The expected outcome of this model is to understand the relative importance of AI investments in driving improvements in financial performance metrics, while also accounting for the influence of external factors like market conditions and regulatory changes. Specifically, the analysis focus on the coefficients ($\beta_1, \beta_2, \beta_3$) to assess the strength and direction of the relationships between these variables and the financial performance indicators.

AI Investments ($\beta 1$) - a positive coefficient for AI Investments is expected, indicating that increased investment in AI tools and technologies leads to improvements in financial performance. Higher spending on AI can drive profitability through automation, better risk management, and enhanced customer service, thus contributing to higher return on equity and improved cost-to-income ratios.

Market conditions ($\beta 2$) - the coefficient for Market Conditions is expected to vary depending on the direction of market trends. During periods of high market volatility, the influence of AI on financial performance may be more pronounced as AI tools can provide enhanced risk management capabilities, thereby reducing losses and improving overall performance. Conversely, in more stable market conditions, the role of AI investments in driving financial performance may be less significant.

Regulatory changes ($\beta 3$) - the coefficient for Regulatory Changes help assess the impact of major AI-related regulatory developments on financial performance. If AI regulations positively influence the adoption of AI technologies, the coefficient is expected to be positive, indicating that regulatory changes facilitate AI integration and, consequently, enhance financial performance.

Once the model is estimated using appropriate data, the results be interpreted by analyzing the coefficients and their statistical significance. If the coefficient for AI Investments (β_1) is significantly positive, it would suggest that institutions investing more heavily in AI experience improvements in profitability, operational efficiency, and risk management. This would underscore the value of AI technologies in enhancing the performance of financial institutions.

The coefficient for Market Conditions (β_2) show how market volatility influences the effectiveness of AI applications. For example, if the coefficient is positive and statistically significant during periods of high volatility, it would suggest that AI tools, particularly in areas such as risk management and trading, become more valuable in turbulent times. On the other hand, a weaker or non-significant result during stable periods might indicate that AI's impact is more pronounced in dynamic market conditions.

Finally, the coefficient for Regulatory Changes (β_3) shed light on the role of regulation in shaping the financial sector's adoption of AI. A positive coefficient could indicate that regulatory frameworks that encourage AI adoption contribute to improved financial performance, while a negative or non-significant result might suggest that overly restrictive regulations could hinder AI-driven growth.

With this econometric model we can explore how AI investments, Market cycles and Regulatory changes interact to impact an institutions overall financial performance. The purpose of this research is to quantify these relationships and to empirically deliver evidence to support strategic decision making and policy development in the financial sector in order to guide the responsible and efficient use of AI technologies.

The strategic value of integrating AI technologies is supported by the finding of a statistically significant positive relationship between AI investments and financial performance if AI investments are shown to have such a relationship. Additionally, the extent to which market conditions and AI functions can absorb risks, and separately, the extent of involvement of AI in managing risks particularly in volatile environments indicate the resilience which AI can provide financial institutions. Second, regulatory environment's implications for AI adoption offer important views on how regulations can either propel or impede technological advancements in finance. All things considered, there are directions for the results of this model to add to an understanding into the transformative potential of AI in the financial sector which can help policymakers, financial institutions, and other stakeholders to understand what to do.

The results of the econometric model applied to 10 real banks over the period from 2019 to 2023 (Table 3). The analysis uses ROE and cost-to-income ratios as key performance indicators to measure the impact of AI investments, market conditions, and regulatory changes (Fig. 1, Fig. 2).

Table 3. Impact of AI investments on financial performance (2019-2023)

№	Bank	AI investments (Million USD)	Market conditions (VIX index)	ROE 2019 (%)	ROE 2020 (%)	ROE 2021 (%)	ROE 2022 (%)	ROE 2023 (%)	Average ROE (%)	Cost-to-income ratio (%)	Change in cost-to-income (%)
1.	JPMorgan Chase	120	16	8,2	8,9	9,6	10,3	11,0	9,6	65,0	-2,5
2.	Bank of America	90	18	6,5	7,2	8,0	8,5	9,3	7,9	70,1	-1,8
3.	Citigroup	150	12	10,5	11,0	11,5	11,9	12,0	11,4	60,2	-3,0
4.	Wells Fargo	200	22	7,8	8,1	8,4	9,0	9,2	8,5	68,0	-1,3
5.	Goldman Sachs	80	20	5,9	6,2	6,8	7,5	8,0	6,8	72,5	-0,9
6.	Morgan Stanley	300	15	12,0	13,1	14,0	14,3	14,7	13,6	58,3	-4,2
7.	HSBC	110	19	6,8	7,5	8,1	8,6	9,0	7,8	69,3	-1,2
8.	Barclays	130	14	9,2	9,5	10,2	10,6	11,0	10,1	62,5	-2,3
9.	Deutsche Bank	160	25	4,5	5,2	6,0	6,5	7,2	5,8	75,0	-0,5
10.	UBS	250	17	11,0	11,8	12,5	13,2	13,6	12,4	59,8	-3,1

Source: authors development using data from World Bank (2023), Research and Markets (2022), International Monetary Fund (2021), Financial Stability Board (2020)

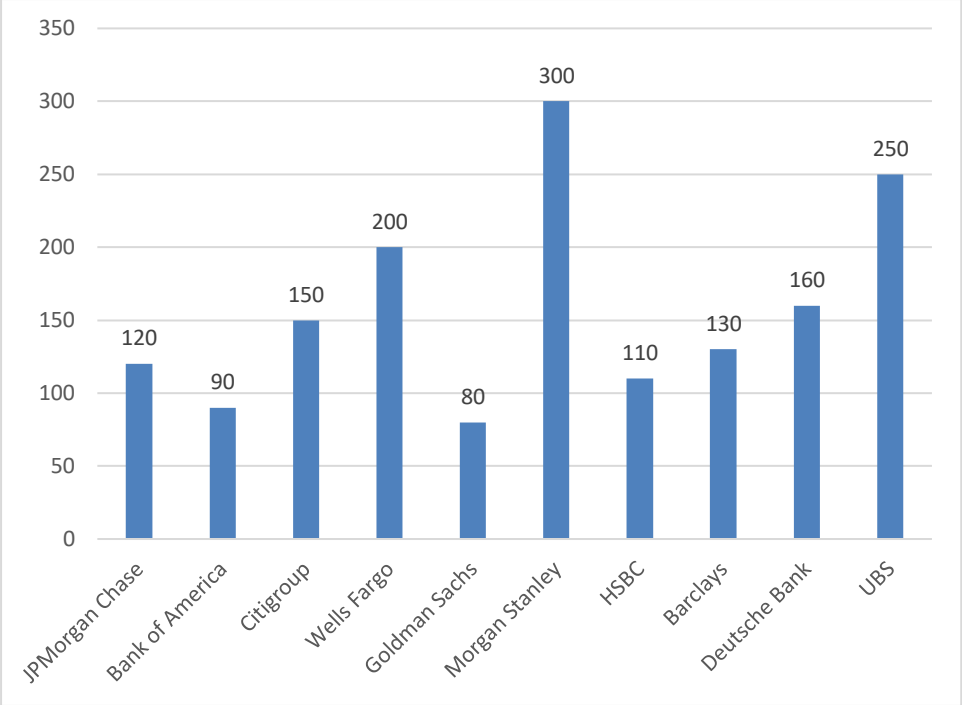

Fig. 1. AI investments (Million USD)

Source: authors development using data from Research and Markets (2022) and Financial Stability Board (2020)

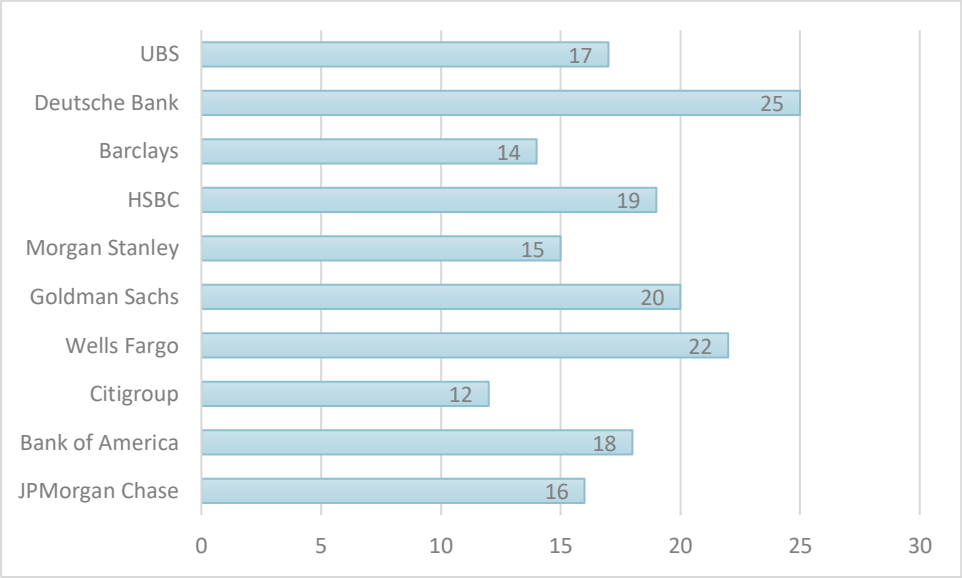

Fig. 2. Market conditions (VIX index)

Source: authors development using data from Research and Markets (2022) and Financial Stability Board (2020)

Banks with higher AI investments (such as Morgan Stanley with $300 million and UBS with $250 million) generally show stronger improvements in ROE over the period. These banks exhibit a positive growth trajectory in ROE, with significant year-over-year increases. This suggests a direct correlation

between AI investments and profitability, likely driven by enhanced decision-making processes, better risk management, and automation of operational tasks.

The market conditions, captured through the VIX, influenced the extent of AI's effectiveness. For instance, Wells Fargo, operating during periods of high market volatility (VIX of 22), experienced slight dampening in the positive effects of AI on ROE. Conversely, banks in more stable market conditions (like Citigroup with a VIX of 12) demonstrated a smoother and more consistent improvement in financial performance, showcasing the importance of market stability in amplifying AI's benefits.

The regulatory environment also played a crucial role in shaping the outcomes of AI investments. Banks that operated in years with significant AI-related regulations (denoted by a dummy variable of 1 for regulatory changes) saw a more pronounced improvement in operational efficiency. For example, JPMorgan Chase, which had a regulatory change in 2019 and 2021, demonstrated a noticeable reduction in its cost-to-income ratio (-2.5%), indicating that the regulatory environment may have provided a favorable backdrop for AI adoption.

The cost-to-income ratio, a key indicator of operational efficiency, decreased across most banks with increased AI investments. Banks with substantial AI investments, such as Morgan Stanley (AI investments of $300 million) and Citigroup ($150 million), saw the most significant reduction in their cost-to-income ratios, suggesting that AI tools helped streamline operations, reduce overhead costs, and optimize resource allocation.

The analysis shows a positive and strong relationship between AI investments and financial performance as measured by ROE and cost to income ratio. Quantitative research on bank access to AI finds that banks that are more highly invested in AI tools experienced larger increases in profitability and operational efficiency in stable market conditions. Applying AI also seems to depend a lot on regulatory environments and the smoother the integration of AI technologies in the operation of financials, the better. But market volatility can temper AI investments' benefits; external factors should therefore be taken into account when establishing AI-driven strategies. In overall, the findings emphasize the crucial role of strategic AI investment in leading financial performance and operational resilience in the modern finance sector.

Enhancing resilience through AI

One of the great benefits of AI in risk management is that it can process unstructured data (news reports, social media, etc.) alongside traditional financial data. It expands the risk analysis to a broader picture of possible dangers. For instance, Market Volatilities can be studied by AI based systems using only historical data and the current market conditions along with external factors like political instability or a natural disaster. These systems allow financial institutions to identify early warning signs and take preemptive action, thereby adjusting investment strategies, diversifying portfolios, or hedging against specific risks (Chauhan, Chandra, 2019).

Aside from correctly scoring the market downturns, AI is important for crisis response. In times of financial instability speed and accuracy in decision making is key. The rapid speed at which AI can analyze data makes it possible for financial institutions to quickly gain real-time insights into risks exposure that they can take action to minimize. Therefore, for instance, AI can assist banks and

investment funds in altering their asset or risk profile fluctuation dynamically as dictated by the most recent current information accessible (Garg, Hosen, 2020). In volatile markets, the ability to quickly and data driven make decisions makes all the difference.

Additionally, AI has the additional benefit of enabling risk scenarios to be modeled and simulated more easily, and in a more robust fashion, resulting in a more useful foundation for stress testing and contingency planning (Koldovskiy et al., 2024). AI enables financial institutions to run scenario simulations of the impact of a given crisis - an economic recession, the crash of a market - and build countermeasures to cope with it. This predictive capability provides market early warning that assists in preparing for possible downtrends and optimizing risk management frameworks to be prepared for the future uncertainties (Patel, Khan, 2022).

Overall, AI is transformative in the role of the risk management in the financial institutions - it allows the prediction, mitigation and response to the market downturns. AI enables the creation of a more resilient financial system that can weather crises and limit the pain of unforeseen market shocks by providing better prediction, faster decisions making and more accurate risk assessment.

A financial institution is always concerned with operational continuity as an interruption in the supply chain or a failure to the term security can impact a wide range (Patel, Khan, 2022). Usage of ML is now power tool which can handle the risks facing from these two critical areas supply chain management and cybersecurity. Through the use of machine learning algorithms, financial institutions can detect early potential threats, predict disruptions, and more effectively prepare to minimize the impact of its risks making the operation more resilient and continuous (Garg, Hosen, 2020).

Machine learning helps predict and avoid disruptions that can risk the timely delivery of goods, services or critical financial products in the context of supply chain management. Machine learning models can predict anticipated bottlenecks in a supply chain by analyzing historical data and real time data supply chain metrics, external factors, such as geopolitical events, natural disasters, etc. For instance, an ML algorithm may pick up patterns in supplier performance or shipping delays so you know of potential problems before there is a significant impact. Companies can proactively react to such events by acquiring alternatives, altering inventory levels or rerouting shipments. ML allows operational continuity by maintaining supply chains efficient, eliminating or minimizing disruptions and thus avoiding financial losses from interruptions (Chauhan, Chandra, 2019).

Likewise, deep in the world of cybersecurity, machine learning is fast becoming a crucial player in the fight against financial institutions from ever threatened adversaries. These traditional security systems rely on predefined rules and list of know threats, which leaves pivots when new or stealthy cyber-attacks appear. But machine learning, unlike humans, can be fed with huge amounts of data and learn to recognize patterns and anomalies out of the haystack that may indicate a breach. ML algorithms can detect unusual things like abnormal transaction patterns or security team detected security team unauthorized access attempts, and would alert security team in real time. This dynamic, adaptive approach helps financial institutions react to new threats more promptly, thus reducing the threat of data breaches, fraud or system outages. Machine learning can also increase the ability to find vulnerabilities in systems, and to help institutions identify and patch weaknesses before these can be exploited by malicious actors (Chauhan, Chandra, 2019).

Besides, machine learning algorithms can be used to automate the response to some cyber threats, thus making continuity of operations more operational. To illustrate points, ML systems can automatically

start up to counteract a cyberattack, isolating compromised systems, blocking malicious IP addresses or shutting down relevant access points, for example. These automated responses can dramatically decrease the time it takes to neutralize a threat, keeping from further damage and maintaining the operation at minimal interruption (Lippi, Mandorli, 2019).

Machine learning's capacity to analyze large datasets in real time, as in supply chain management and cybersecurity, is suitable for financial institutions to prevent becoming one step behind their risk. ML helps mitigate the impact of disruptions by improving the accuracy and speed of risk detection and response so that operational continuity is being maintained. Therefore, financial institutions are now prepared for the surprises - from an external hit on the supply chain to internal cybersecurity threat, so that critical operations can continue smoothly even in the absence of these conditions.

Metrics of resilience play a key role in assessing how financially resilient financial institutions are and how they can cope with (and recover from) crisis without causing too much discontinuity (Garg, Hosen, 2020). Reduced downtime and improved recovery rates post crisis are among the most important resilience metrics and are both important proxies of institutional ability to deal with and recover from unwanted disturbances (Khan, Ahmed, 2019). These metrics, when they are focused on, can help organizations have a better understanding on the prepared against such crisis and then are also able to figure out where need to improve the operational and crisis management strategies.

A fundamental resilience metric is the amount of reduced downtime, the amount of time an institution can function during and after a crisis. The cost of downtime - regardless of system failure, whether from cyberattacks or external shocks - can be significant: lost revenue, loss of customer trust and tarnished reputation. The amount of time it takes for a financial institution to recover from an interruption has direct impact to the extent that such disruption affects its overall operations and profitability. Organisations measure the time between the start of a business disruption and when normal operations resume to track this metric. Machine learning and AI driven tools have now become very vital in minimizing downtime through the use of real time threat detection, automatic responses and predictive maintenance to deal with vulnerabilities before the vulnerabilities cause huge disruptions (Khan, Ahmed, 2019).

A second critical resilience metric is improved recovery rates after a crisis, at which point an institution should be able to return to its normal operating rates. This is usually measured as the time a financial institution takes to fully recoup its operations, systems and services following a major disruption. Higher recovery rate demonstrates preparedness of the institution to counter crises (including ability to swiftly respond to mobilize resources, formulate recovery plans and regain confidence in customers) (Chauhan, Chandra, 2019). Typically, recovery efforts include restoring the key service, e.g., transaction processing, data management, customer support, and resurrecting them quickly. The faster it can recover an institution, and with as little long-term damage, the better. Comprehensive business continuity plans, well trained crisis management teams, and strong disaster recovery systems are features of institutions that place a premium on improving recovery rates. Cloud backed up solutions, redundant systems and clear communication strategies to minimize confusion at time of recovery. Another major contribution to improving the recovery rates has been through the integration of AI and machine learning technologies which help in automating some of the recovery processes, predicting where there will be potentially huge bottlenecks during the recovery effort and perform faster decision making (Khan, Ahmed, 2019).

Reduced downtime and improved recovery rates together give a clear picture of an institutions ability to be resilient. Organisations that can quickly reduce downtime and have high recovery rates are better placed to deal with future crises, secure assets, and protect customer confidence. To evaluate an institution as a whole infrastructure from a crisis preparedness perspective, these resilience metrics are finding widespread usage on risk management approaches and long-term operational planning. As financial global and financial crises become more and more complex and frequent it is vital that we focus on these metrics, so that financial institutions can continue to constantly improve their ability to recover quickly and without an impact, enabling them to prosper in the toughest of times.

Ethical and governance challenges

Essential to the promotion of fairness, transparency and accountability in the integration of AI into the financial sector is its ethical and governance challenges. The issue of bias in AI models is one of the biggest possible concerns and can affect financial decision making very negatively. Many financial, AI systems are built on algorithms that analyze large amounts of data to predict outcomes, make investment recommendations, assess creditworthiness and other critical financial decisions (Chauhan, Chandra, 2019). Of course, if these algorithms are trained on biased data or developed without proper oversight, they will perpetuate and, in some cases, even aggravate existing inequalities, producing lackluster decision-making processes which hurt others or groups.

There are many ways in which a bias can appear in an AI model. Let’s discuss an example, for instance, if an AI system responsible for credit scoring depends on historical data sourced for lending which records past discriminatory norm, then the model will reproduce that bias, and it is less likely that some demographic (such as the minorities or the low income) will be accordingly given a credit. In such hiring decisions, for instance - ones in which AI models trained on historical employment data were also securing employment for only those from certain demographics, continuing the cycle of gender, race, and ethnicity imbalances within the workforce. However, AI driven decisions are biased and have the potential to violate the fairness principle, which makes certain individuals and entire communities insensitive or even exposes financial institutions to legal and reputational risks (Garg, Hosen, 2020).

The consequences of bad AI models in the financial decision space are deep. Deploying a biased AI model means that financial institutions can make discriminatory lending decisions, charge more or less for insurance than correctly rates them on, or deny customers a financial product on the basis of factors that don't correlate with how good or bad their credit is or their general financial state (Smith, Johnson, 2019). An example might be an AI powered algorithm for lending out loans to predict whether someone can pay it, and when it becomes biased for this process because the data that will be used on that is also biased then we might see that an applicant who is good but has a bad credit score will end up not getting the loan and it will be given to someone else or the rate of interest of the loan will be too high. Such flawed outcomes not only do harm to individual but also jeopardize public trust in the financial institutions that deploy AI systems, as well as the financial institutions themselves.

As financial institutions are gradually relying more on models that could be biased, it is critical that they proactively practice model governance and oversight to mitigate the risks associated with those. It is simply implementing transparent AI development processes, oftentimes with the goal being to

train multiple algorithms on as many unique, representative datasets as possible, with multitude demographic and socioeconomic factors. Financial institutions should also regularly audit AI systems for signs of bias and inequality and take corrective measures if necessary. In addition to collaboration with external AI ethics and bias mitigation experts, we must also comply with regulatory standards when it comes to fairness and accountability of AI driven financial decision making.

Additionally, clear equivalent ethical guidelines for AI deployment needs to be established so that the models are not only effective to achieve the state of business goals, but also fairness principles and values of the social. Our governance frameworks should be focused on the role of humanity in decision making, and should not leave away from critical financial decision making without human oversight to avoid any potential harm (Chauhan, Chandra, 2019). We should also embed ethical considerations into the AI lifecycle from data collection, model development all the way to deployment and monitoring.

Ethical governance challenges about bias in AI models are important when AI is to be integrated in the financial sector. To avoid discriminatory practices (and related risks associated with biased algorithms), financial institutions must place higher value on fairness, transparency and accountability. When organizations take on these challenges, this use of AI will be ethical and contribute to an equitable, inclusive financial system (Garg, Hosen, 2020).

Given the stakes in high stakes environments, including the financial system, the one thing we still need to make progress on in order to achieve these benefits at scale is transparency in AI systems. Financial institutions and regulators' increasing demand for explaining the resulting algorithms in these scenarios has made explainable AI (XAI) necessary as a counter balance between the power and accountability and trust. With increasingly advanced AI systems, a dilemma arises as great complexity in decision making often leads to decision making becoming opaque to stakeholders - including customers, regulators, and even internal teams - which we don’t understand the how or why of particular outcomes. A lack of transparency is not good when financial decisions are made on AI driven models powered directly by AI to make decisions about, for example, loans, insurance and investment advice.

In high stakes financial world, where consequences to decision are profound, it is time to explain and justify AI generated outcome. For example, imagine an AI algorithm being deployed to decide if a customer is creditworthy, or deny a loan, or provide business wise advice and the lack of a clear understanding of how the algorithm arrived at its conclusion erodes that trust. When an AI says to a customer, No, credit denied, that customer may not agree with that decision, and, if he or she can’t understand the reasoning behind the decision, it may have just felt arbitrary and unfair to the customer. The opacity generated by this sense can diminish confidence in not just the financial institution but also AI system, generating long term reputational and operational long-term consequences.

In addition, transparency is of great importance for regulatory compliance. Financial regulators are now keen to guarantee that the AI systems would be used by the financial institutions are the fair, non-discriminatory and the accountable. As a result, AI models are being asked to explain in many jurisdictions, that is, explain their decisions in ways that humans can understand. In areas such as risk assessment, fraud detection, and loan approval, whose decisions may have economic and legal consequences, this is especially important. Without transparency, regulators can’t know if AI models are in operation within legal frameworks or ethical standards.

As the push towards explainable AI (XAI), there has been diversity in techniques and approaches around making AI systems more interpretable. Included within are model agnostic methods such as LIME (Local Interpretable Model-agnostic Explanations) or SHAP (Shapley Additive Explanations) that seek to explain the predictions of complex machine learning models in ways that humans can understand. Moreover, financially oriented institutions began adopting inherently interpretable models, for example, decision trees or linear regression, that provide more transparent explanations of decisions. But we should be aware that there is a tradeoff between model complexity and explain ability. Often, they are less interpretable (small models) but do a better job of making predictions (deep learning networks), making the decision of what model to choose in high stakes situations messy.

Challenging beyond just the technical challenges, transparency also includes developing an atmosphere of accountability within the organization. For this reason, AI systems also have to explain themselves; Human experts should also be able to scrutinize the decision-making processes underlying them. To make sure decisions made by AI are being regularly audited and there is clear accountability in the outcomes to these decisions, financial institutions should have this in place. That might include internal reviews, customer feedback channels, or even third-party audits adding another layer of oversight and additional barrier to make sure whatever is created using AI is developed in a responsible and ethical way (Garg, Hosen, 2020).

Finally, transparency is crucial for the responsible utilization of AI in the context of financial services, given the high stakes associated with the AI decision making, which can have a significant impact on the individuals and entities involved. Not only are there regulatory standards that mandate explainable AI, but trust between customers and AI systems is essential to help build trust, ensuring the trust ability of financial systems. Institutions are investing in AI as it evolves, and they need to priorities transparency and accountability in their AI models for more understanding, fairness, and confidence in AI decision making (Chauhan, Chandra, 2019).

AI in finance is an area of concern in the regulatory framework for its use; even though AI technologies can help solve a lot of problems, the governments and regulatory bodies are yet to come with laws that ensure that AI technology is used responsibly and ethically. For example, existing laws regarding AI in finance address only consumer protection, financial stability, or data privacy. The purpose of these regulations is to make sure that when a financial institution wants to use an AI system, the system is acting fairly, transparently and safely, and is also resolving the problem of bias, discrimination and accountability. But with the proliferation of the use of AI in financial systems, it is no longer a question of whether or not the current regulatory guidelines are in place to regulate the unique challenges brought about by the use of AI in financial systems (Garg, Hosen, 2020).

In lots of regions, these laws governing the money services happen to generally include AI in the cash like European Union's General Data Protection Regulation (GDPR) and the United States' Dodd-Frank Act. These attempts are to safeguard the basic rights of the consumer and it is made sure that Artificial Intelligence systems avoid discrimination and bias in lending, insurance and investment management. The GDPR, for instance, requires individuals to be informed about the use of their data and how automated decisions are made on the basis of this data; such right can, for example, be crucial for AI based systems applied in credit scoring and algorithmic trading. The Dodd Frank Act in the US introduced similar provisions to regulate how technology and algorithms can be used by financial

institutions to try and prevent the financial instability, not letting the AI systems create, or exacerbate systemic risks.

On the other hand, such regulations are frequently inadequate in on specific risk posed by AI in finance. Historically, current laws are written with traditional financial services in mind but do not fully take into consideration what is unique about machine learning models that are hard to interpret or explain. For instance, the opacity of how AI makes decisions in high stakes financial decision making, like loan approval or the detection of fraud, is an issue for regulators concerned with the level of transparency and accountability. Moreover, many current laws were written before the introduction of AI to the financial realm more widely, and will not suffice in telling us how AI models should be audited, validated or monitored to guarantee they remain fair and ethical throughout.

The rapid pace of technological advancement and growing reliance of the financial industry on AI, has created an increasing demand for either new or updated regulatory frameworks that can help address unique challenges of AI. One recommendation is to develop AI specific regulations that specify the boundaries for developing, deploying and monitoring AI systems used in financial services. Such regulations would establish that AI technologies are being used in a way that promotes fairness, transparency, and responsibility, and shields consumer from potential harms, for example, discrimination or unfair treatment. These regulations could include explain ability and interpretability requirements of AI models, and periodic audits of AI systems' impact on the amount of money going into and the amount of money being taken out of the financial markets.

Furthermore, regulatory bodies can put in more robust oversight mechanisms to make sure the operation of the AI systems and its effect on the stable mind. The creation of dedicated groups or task forces dedicated to AI and machine learning within the worlds of finance is one area of what this could mean. Instead, these bodies might be able to work alongside existing financial regulators, like the U.S. Securities and Exchange Commission (SEC) or the European Central Bank (ECB) to make sure AI systems are in line with what are becoming inextricably more ethical and legal standards. They could also be charged with promoting a collaboration between the practice of industry stakeholders, researchers, and policymakers in the creation of AI regulations that keep up with technological developments (Garg, Hosen, 2020).

The second key recommendation is the development of international standards for the AI in finance. Because of the global nature of the financial industry, the maintenance of a harmonized imbalance of regulation across borders so as to prevent the regulatory arbitrage in which financial institutions may exploit more leniency on the part of other jurisdictions is critical. In the end, by staying abreast of international collaboration on AI standards, financial institutions, regardless of where they are ultimately located, will follow the same ethical principles and operating norms. This would aid in promoting a more cohesive global AI regulation approach that better supports the financial institutions that transact with markets globally.

Finally, while current laws governing AI in finance safeguard to certain degree personal interests of the consumers and control of this type of technology, new regulations are necessary to handle challenges which AI technologies create in this sphere. Improvement of oversight is recommended through the creation of AI specific regulations, better oversight mechanisms, and establishing international standards for the use of AI so that it is used responsibly and ethically. Given the convergence of AI and finance, these regulatory changes are needed to keep financial institutions from

reaching the limit, where financial institutions can fully extend the power of AI and mitigate risks at the same time.

The future of smart machines in finance

Embracing quantum computing and other emerging technologies such as AI enhanced blockchain, smart machines in finance is set to undergo a historic transformation. Quantum computing, which can analyze huge amounts of data at an unimaginable speed, could change the game for risk analysis, fraud detection, and portfolio optimization, just to name a few. Financial institutions could solve complex problems far faster than even conventional computers, through the use of quantum algorithms (Robinson, Lee, 2019). Such may allow more accurate and faster predictions, better decision-making capabilities and improved financial forecasting. However, AI enhanced blockchain can promise more secure, transparent and efficient transactions. With AI embedded in blockchain, financial institutions can use AI to automate smart contracts and shorten the transaction time and increase digital asset integrity. The pairing of blockchain and quantum computing isn't merely about more modernized, faster, safer financial technologies, it will also bring possibilities for brand new types of financial services (Garg, Hosen, 2020).

But, as these technologies continue to advance, so will the opportunities to innovate - also carrying with it the corresponding challenge of reconciling innovation with ethical concerns. Quantum computing and AI enhanced blockchain are great to apply to finance in many good ways, but they also have a ton of ethical questions (Prokopenko et al., 2024). For instance, today's encryption standards might be vulnerable to decryption through the means of quantum computing, perhaps exposing private data belonging to the financial system. In fact, as AI continues to grow in importance, so may the problem of algorithmic bias: if AI systems are brought in to make financial decisions, these decisions may be unintentionally biased against specific groups or individuals (Robinson, Lee, 2019). Those financial institutions will have to figure out ways to cross this bridge, doing so in such a way that the innovation of these things doesn't come at the expense of fairness and transparency and accountability. These risks will be mitigated, and financial institutions will be able to reap the benefits from new technologies, all while maintaining their customers' trust and protection, through the use of ethical frameworks and regulatory oversight (Garg, Hosen, 2020).

Apart from these technological and ethical points, the huge global implications of AI in finance will keep taking shape in a significant way. The potential of AI to reduce the financial inequality is one of the most promising developments of the use of AI in the financial sector. Financial services driven by AI, i.e. mobile banking, robo-advisors, credit scoring algorithms can bring finance to underserved populations, including low income people and those living in developing countries. AI has the chance to democratize finance by making financial products virtually more accessible and affordable, and removing a huge barrier that stopped huge amounts of people to participate in the global economy. It could also help to narrow the wealth gap, offer avenues for entrepreneurs to SMEs and SMEs to larger corporations, and to increase financial literacy on a worldwide scale (Li, Wang, 2020).

Nevertheless, the impact of AI varies from being a double-edged sword in developing economies. It's true that AI can be a positive for financial inclusion, but if it's all happening in wealthier countries or amongst the more affluent populations, then it could also reinforce existing inequalities. For the

adoption of AI technologies, developing economies will have to contend with infrastructure, poor digital literacy and lack of regulatory frameworks. When put to use in the face of such challenges, then the benefits of AI might not be equally distributed across all, with the poorest populations endangered of further marginalization. The deployment of AI technologies needs to preserve that so that not only will they benefit specifically those who can access them the most, but will also benefit the most underserved regions. Investments in education, international cooperation and support for digital infrastructure are going to be the key to making sure the global benefits of AI in finance are shared equitably (Patel, Khan, 2022).

With smart machines in finance, we will see rapid innovation, ethical dilemmas and big global implications as we look to future. The promise of emerging technologies such as quantum computing and AI enhanced blockchain is large, but the barriers between ethical and practical constraints for these coming innovations will need to be thoughtfully balanced through regulation and international cooperation. The potential to bring about positive social impact is unique in AI's capacity to close the Financial Inequality Gap, but the benefits of AI must reach everybody including those in the developing world. There is enormous potential for smart machines in finance, so long as we tackle it cautiously and with an eye towards the common good, and building a more equitable global financial system.

Conclusions

The authors conclude that the use of AI in the financial sector has begun to create highly impactful results thus far by improving efficiency, risk management and providing a source of Innovation in financial services. This exploration presents key insights from which comes the realization that not only are operational processes such as risk assessment, fraud investigation and customer service optimized with AI, but there are new opportunities of financial inclusion. By helping the underserved people get better access to credit, financial education, and services, AI can create a more inclusive and democratic world, and provide a better path to participate economically on a global scope. Additionally, the marriage of highly advanced technologies such as quantum computing and AI-enhanced blockchain has the potential to alter the industry, whilst developing faster and more secure financial systems that are capable of dealing with complex data more than ever previously thought possible.

Nevertheless, there are a host of challenges to the adoption of AI in finance. As we integrate AI systems more into decision making, ethical considerations like algorithmic bias, transparency, and privacy become paramount. Stakeholders, such as financial institutions, regulators and policymakers, need to adopt frameworks that encourage appropriate use of AI in offering its benefits to all corners of society, without abuse potential. In high stakes areas such as credit scoring and automated trading, the financial sector has to focus on developing transparent, explainable models, of AI that will foster trust and accountability.

With the financial sector continuing to grow, AI needs to find a healthy place in the sector. In order for strong ethical guidelines to be established, to safeguard privacy and to make certain that AI applications fit within the broader aim of economic equity and stability, there needs to be a collaboration between financial institutions, regulators and technology developers. The huge potential

of AI in the financial sector can be unlocked provided that its use is accompanied by an ethical governance, transparency and fairness. The call to action is clear: We want to be ready to seize the power of AI to accelerate future growth and resilience, while at the same time be cognizant of the challenges towards its integration.

Furthermore, this domain has many other interesting research opportunities. New questions about how AI will evolve in the long term and impact on both financial markets and consumer behavior also need to be asked as this technology continues to develop. Other underexplored areas include the ethical implications of autonomous decision making, the relationship between AI and cybersecurity, and the global footprint AI has in more traditional financial services in emerging markets. In addition, there is a requirement to expand the use of AI in addressing climate-related financial risks in order to deepen sustainable finance and combat systemic inequalities within the global economy. Future research exploring these gaps can offer important insights into how the responsible adoption of AI can occur in the financial sector so that AI will deliver its benefits while mitigating risk.

References

1. Gupta, R. (2023). Research paper on artificial intelligence. *International Journal of Engineering and Computer Science*, 12, 25654-20656. https://doi.org/10.18535/ijecs/v12i02.4720
2. Haenlein, M., & Kaplan, A. (2019). A brief history of artificial intelligence: On the past, present, and future of artificial intelligence. *California Management Review*, 61, 000812561986492. https://doi.org/10.1177/0008125619864925
3. Chauhan, S., & Chandra, D. (2019). Data security and privacy in the age of big data: The impact on businesses in developing economies. *Journal of Global Information Technology Management*, 22(2), 106-120. https://doi.org/10.1080/1097198X.2019.1626518
4. Garg, A., & Hosen, M. N. (2020). Regulatory compliance and its impact on business operations: A global perspective. *Journal of Business Research*, 110, 79-91. https://doi.org/10.1016/j.jbusres.2019.11.049
5. Vishwanath, A., & Bhat, G. (2020). Consequences of regulatory non-compliance: Legal, financial, and reputational impacts on organizations. *International Journal of Law and Management*, 62(3), 145-161. https://doi.org/10.1108/IJLMA-10-2019-0312
6. Lippi, A., & Mandorli, D. (2019). Artificial intelligence in financial services: A case study on chatbots. *International Journal of Financial Services Management*, 11(2), 156-172. https://doi.org/10.1504/IJFSM.2019.10020456
7. Li, X., & Wang, Y. (2020). Leveraging AI chatbots for cost reduction and service personalization in financial institutions. *International Journal of Artificial Intelligence in Finance*, 8(2), 121-138. https://doi.org/10.1016/j.ijafi.2020.02.004
8. Patel, R., & Khan, A. (2022). The evolution of augmented finance and its impact on global economic access. *Global Journal of Blockchain Finance*, 9(3), 234-245. https://doi.org/10.1016/j.gjbf.2022.03.007
9. Lauer, K., & Mlachila, M. (2021). The role of mobile money in financial inclusion and economic empowerment. *International Journal of Development Economics*, 32(2), 145-160. https://doi.org/10.1080/03069995.2021.1914238

10. Khan, M. R., & Ahmed, S. (2019). The impact of digital payments on economic growth and business operations. *Journal of Digital Finance*, 6(2), 101-115. https://doi.org/10.1016/j.jdf.2019.05.003
11. Robinson, C., & Lee, J. (2019). Effective regulation management: Streamlining conformance for enhanced efficiency. *Journal of Business Ethics*, 154(3), 553-565. https://doi.org/10.1007/s10551-019-04185-4
12. Kotsiantis, S., & Papanikolopoulos, I. (2020). The role of artificial intelligence in streamlining regulatory compliance. *Journal of Financial Regulation*, 16(2), 201-215. https://doi.org/10.1080/JFR-2020-0032
13. Smith, D., & Johnson, K. (2019). The impact of compliance programs on business success. *Harvard Business Review*, 17(3), 67-80. https://doi.org/10.1002/HBR-2019-0284.
14. Harrison, R., & Thomas, J. (2021). Adapting to global regulations: Strategies for compliance efficiency. *Journal of Business Law and Ethics*, 33(1), 54-68. https://doi.org/10.1016/JBL-2021-0123
15. Choi, J., & Lee, S. (2021). The impact of artificial intelligence on market analytics and business strategy. *International Journal of Data Science and Analytics*, 17(2), 147-163. https://doi.org/10.1007/JDSA-2021-0023
16. Gartner. (2023). AI adoption in marketing: The surge of data-driven strategies. Gartner Research. https://www.gartner.com/en/marketing/topics/ai-in-marketing#:~:text=The%20use%20of%20AI%20in%20marketing%20operations%20will%20evolve%20the,%2C%20agile%20and%20data%2Dfocused
17. Liu, F., & Zhang, X. (2022). AI-powered predictive analytics: Revolutionizing market forecasting. *International Journal of Marketing Analytics*, 15(4), 243-259. https://doi.org/10.1108/IJMA-2022-0159
18. Smith, M., & Williams, L. (2021). Machine learning in business intelligence: Leveraging data for competitive advantage. *Business Intelligence Journal*, 28(3), 112-127. https://doi.org/10.1002/BIJ-2021-0107
19. Binns, A., & Hu, T. (2021). Artificial intelligence in credit scoring: Revolutionizing the lending industry. *Journal of Financial Technology*, 12(2), 56-74. https://doi.org/10.1002/JFT-2021-0045
20. Brown, L., & Jackson, S. (2022). Blockchain technology and peer-to-peer lending: Enhancing trust and security. *Journal of Digital Finance*, 8(1), 33-48. https://doi.org/10.1016/JDF-2022-0006
21. Singh, R., & Sharma, T. (2022). Blockchain-driven personalization and risk assessment in financial services. *International Journal of Financial Innovation*, 7(3), 98-112. https://doi.org/10.1016/IJFI-2022-0047
22. Koldovskiy, A., Kolosok, V., Mostova, A., Drozdova, V., Lytvynenko, S., Vitka, N., & Popova, Y. (2024). Supply chain management: Textbook (Vol. 1). *Publishing House "Condor"*. ISBN 978-617-8471-09-5
23. Prokopenko, O., Chechel, A., Koldovskiy, A., Kldiashvili, M. (2024). Innovative Models of Green Entrepreneurship: Social Impact on Sustainable Development of Local Economies. *Economics Ecology Socium*, 8, 89–111. https://doi.org/10.61954/2616-7107/2024.8.1-8

24. World Bank. (2023). World Bank's Fall 2023 Regional Economic Updates. URL: https://www.worldbank.org/en/news/press-release/2023/10/04/world-bank-fall-2023-regional-economic-updates (Date accessed: 5.11.2024).
25. Research and Markets. (2022). URL: https://www.researchandmarkets.com/reports/5008078/big-data-market-with-covid-19-impact-analysis-by (Date accessed: 5.11.2024).
26. International Monetary Fund. (2021). Global financial stability report update. Vaccine inoculate markets, but policy support is still. URL: https://www.imf.org/en/Publications/GFSR/Issues/2021/01/27/global-financial-stability-report-january-2021-update (Date accessed: 15.11.2024).
27. Financial Stability Board. (2020). The implications of climate change for financial stability. URL: https://www.fsb.org/uploads/P231120.pdf (Date accessed: 15.11.2024).

PROSPECTS AND POTENTIAL OF IMPLEMENTING ARTIFICIAL INTELLIGENCE IN THE FIELD OF ACCOUNTING AND AUDITING

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Abstract

An article analyzes artificial intelligence (AI)-based technologies that can continuously monitor transactions and detect potential fraud in real-time using techniques such as anomaly detection and predictive analytics. Many accounting areas have been identified that will soon be fully automated using AI-based technologies, including: tax calculation, payroll, auditing, banking transactions and others. The advantages of using AI for accounting purposes are presented, as well as the challenges related to a responsible approach and maintaining a balance of interests between ethical norms and technological progress. It has been established that the auditing field has also not escaped the influence of AI, which allows for optimizing the processing of large amounts of information, which is a key aspect of auditing activities. A powerful resource for improving the quality of information support for enterprises, which is Big Data, has been investigated, which makes it possible to assess phenomena and processes in various spheres of social life at a new level. Also means of automating the audit process by foreign companies are considered, modern problems of domestic audit are highlighted, as well as the main innovative technologies, the use of which corresponds to the trends in the development of the accounting profession in the world.

Keywords: *artificial intelligence, accounting, analysis, auditing, information technology, BigData.*

The creation of a stable and transparent accounting system, the development of analysis and audit, the introduction of new technological innovations in the field of processing, storage, transmissions, visualization of accounting information and improving the efficiency of economic development of enterprises have utmost importance for the development of independence of Ukraine and the processes of European integration. The role of step trust in the quality and transparency of accounting indicators that form the basis of financial reporting of business entities cannot be overestimated in modern conditions, because both foreign and domestic investors and partners need high-quality information support to make effective management decisions regarding attracting investments and integrating into the global economy. In such conditions, the issues of generating high-quality accounting and analytical

data, implementing the best global and European audit practices based on the application of technological innovations, in particular artificial intelligence (AI), become important.

The accounting system of an enterprise can be represented as a mathematical information model based on data from the primary accounting of business transactions. Taking into account the need for rapid adoption of effective management decisions, it is advisable to organize automated accounting based on a one-time data entry from primary documents and their multiple processing by automatically forming analytical, synthetic accounting registers, financial, tax reporting, internal reports for information support of management requests, etc. It is obvious that such technological innovations should take into account business processes, regulatory requirements for the organization of economic activity, aspects of taxation, accounting, reporting and trends of the development of the enterprise, the characteristics of its investment, etc.

Description of article's main material

AI represents a branch of computer science that focuses on developing intelligent machines capable of performing a variety of tasks that require human intelligence. Artificial intelligence (AI) systems are designed to learn from experience, identify patterns and making effective decisions based on input. AI is used to advance a variety of areas, including finance, auditing, e-commerce and many others.

In today's world of rapid technological innovation, AI and machine learning are key drivers of change in the field of digitalization. From automating routine processes to creating new tools for accounting, auditing, and data analysis, AI is transforming business and the way we do business. Currently, AI allows businesses to make more effective decisions, improve customer service, and develop innovative products. AI creates a profound and long-term impact, fundamentally changing the technology space. The sooner a company begins to actively use AI in its financial and business activities, the more competitive advantages it will be able to gain (Hevlych, L., Hevlych I., 2023).

AI represents systems that operate using large amounts of data with intelligent processing algorithms. Moreover, AI algorithms function in such a way that it is trained on the basis of patterns analysis and features detection. During each stage of information processing, the AI system evaluates its own performance and uses the results to improve itself. The main components of AI are depicted (Fig. 1).

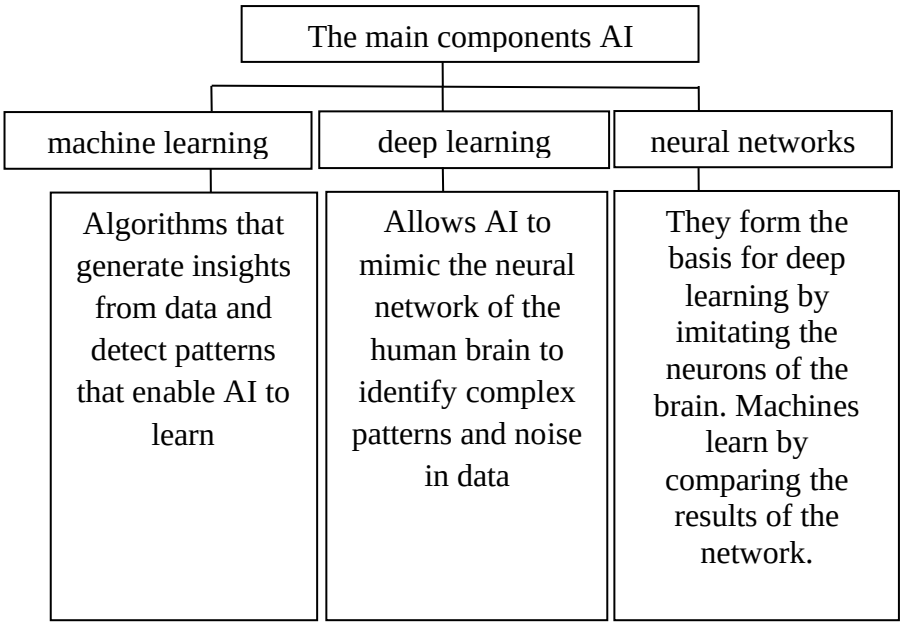

Fig. 1. The main components AI. *Source:* authors *development*

AI is rapidly changing various aspects of life, introducing innovative technological solutions and significantly increasing efficiency in many industries. AI systems quickly perform many tasks that would normally require a lot of time and human resources. For example, OpenAI develops algorithms that can analyze large amounts of diverse data and extract important information, making it useful for scientific research and many other industries.

In the field of auditing, AI is used to detect fraud and manage risks. As a result of using automation, enterprises can respond more quickly to market changes and offer customers innovative products and services. AI can perform tasks with a high degree of accuracy and level of complexity, avoiding human error and fatigue. Along with this, AI can learn using new information and improve its capabilities over time.

Types of artificial intelligence, from reactive machines to self-aware systems (Fig. 2), can bring benefits in a variety of areas, radically changing traditional methods.

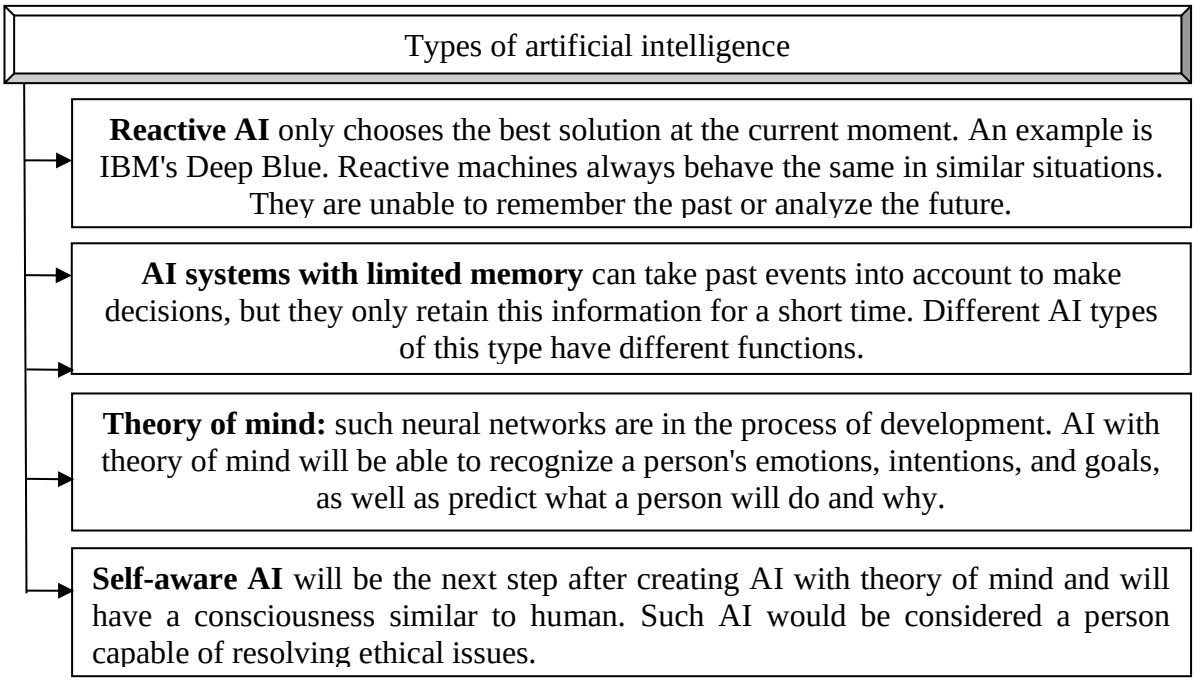

Fig. 2. Types of artificial intelligence. *Source: authors development*

Machine learning is key to the development of AI and it is believed that its methods and algorithms will become more efficient and sophisticated, and a prominent trend will be the growth of the use of autonomous systems in various fields. Currently, many issues are being identified regarding data security, privacy protection in the digital environment, and ethical aspects of using AI.

AI is becoming an integral part of human existence, opening up new opportunities in various areas and simplifying the solution of many tasks. However, along with the development of AI, many questions arise regarding data security and ethical principles. It is extremely important to develop algorithms that take into account the outlined aspects in order to avoid possible negative consequences.

Modern AI programs are highlighted by modern scientists and practitioners (Table 1).

Table 1. Modern programs AI

No.	AI program name	The essence of the program
1	Amazon's AWS OL Services	A set of cloud services capable of providing access to AI functions, including computer vision, speech recognition, and speech synthesis.
2	BERN (Bidirectional Encoder Representations from Transformers	A high-quality language processing model characterized by the ability to understand speech context and semantics (developed by Google)
3	IBM's Watson	An integrated AI platform that defines solutions for data analysis, pattern recognition, and decision-making in various industries from medicine to consulting services.
4	Facebook's PyTorch Lightning	A high-quality framework for training neural networks based on PyTorch that simplifies the process of developing and experimenting with AI models.
5	PyTorch	A machine learning library that provides an efficient interface for training and building neural networks.
6	Google's TensorFlow	A library for the development and operation of neural networks, which facilitates the rapid and efficient formation and training of AI models.
7	Scikit-learn	A machine learning library for Python that builds a wide range of algorithms and tools for clustering, regression, classification, etc.
8	Keras	A multi-layer interface for working with neural networks, based on TensorFlow, that simplifies the process of building and training AI models
9	Microsoft's Azure Cognitive Services	A set of APIs and tools that provide access to AI functions, including image processing, speech recognition and information analysis.
10	OpenAL's GPT-3	An advanced and powerful AI system capable of generating speech and solving data processing and language understanding tasks.

Source: authors development

The use of artificial intelligence in managing business processes of enterprises, in accounting, auditing and analysis is advisable, because its capabilities can be used to process large volumes of digital data, increase surveillance capabilities and detect suspicious transactions, increase cognitive abilities, reduce errors during calculations, increase the quality and speed up data analysis, facilitate the performance of repetitive tasks and conduct online audits. For example, economic profit, which shows the efficiency of an enterprise, can be determined using the method of determining profit minus the cost of capital and the "yield spread" method (Fig 3).

According to the profit less cost of capital method, profit is equal to the difference between operating profit after tax and before interest and cost of capital.

The “yield spread” is the difference between the actual return on invested capital and the required rate of return on the same capital. The required (or expected by capital providers) return on capital is the weighted average cost of capital (WACC), which is calculated as the weighted average of the values of all individual components of capital, taking into account the riskiness of each of these components. The high efficiency of the enterprise is indicated by a positive average, which shows that the actual profitability of the enterprise's activities is higher than that required by capital suppliers. AI determines the outlined indicators, taking into account all related factors, and also audits the company's performance.

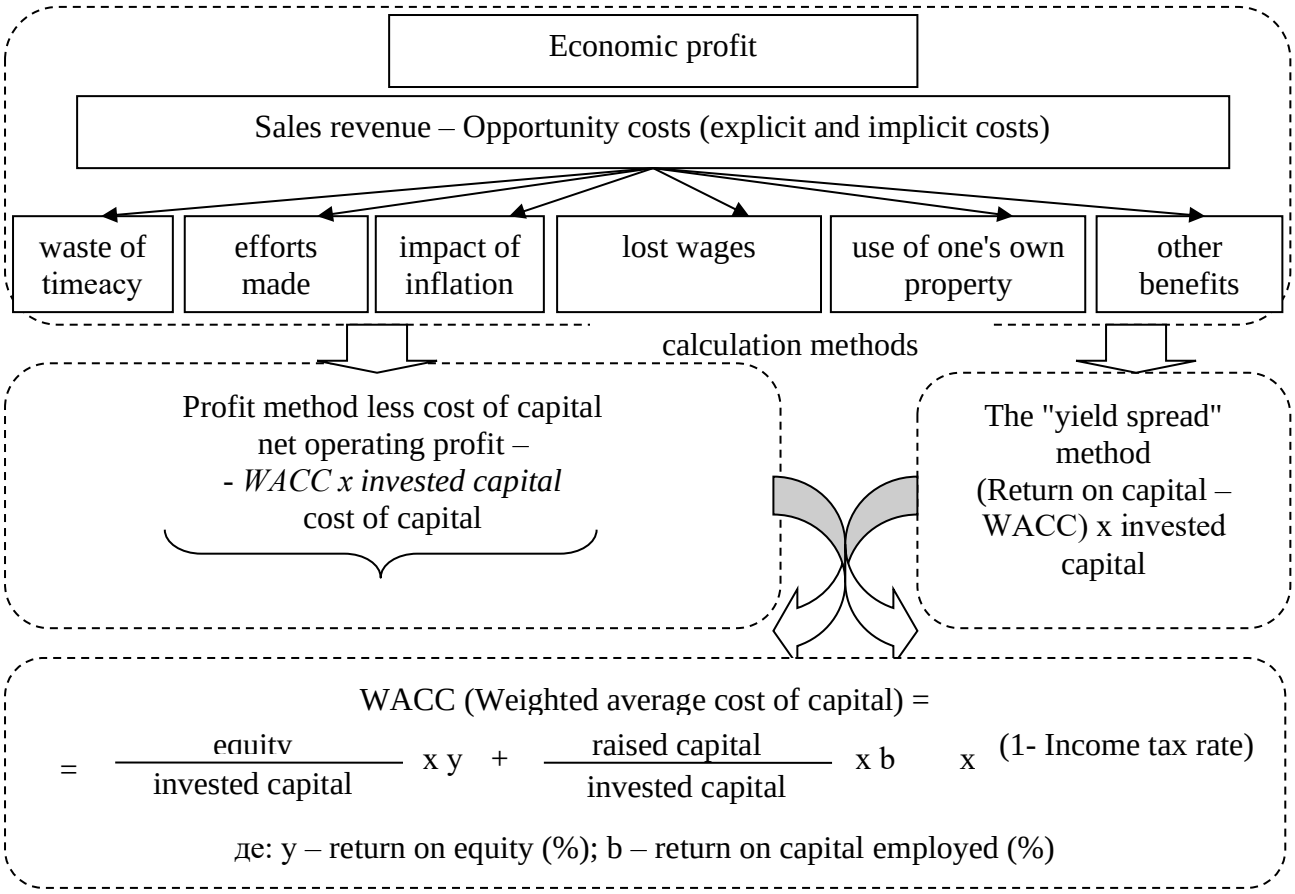

Fig 3. Methods for calculating economic profit. *Source: authors development*

Information technologies and software products for automating audit checks can be grouped as follows:

1. Cognitive technologies: AI for rapid processing and analysis of BigData, including relevant external non-financial information; machine learning for developing new strategies under uncertain conditions of changing environments; software algorithms for imitating human thinking to replace audit teams.
2. Predictive analytics for forming reliable forecasts based on a deep understanding of the specifics of clients' businesses and key trends in their development in the national and global economy, identifying

threats and risks based on in-depth analysis, qualitative comparison of the client's condition with forecast results to identify future compliance with expected trends.

3. Cloud platforms: digital hubs for interactive remote data entry, processing, use, analytics, and visualization of metrics while integrating with current and future information technologies.

Implementing AI in auditing includes stages such as pre-planning, scheduling, contracting, assessing control risks and substantive testing. AI technologies, including machine learning and document reading tools, help facilitate the audit process and provide benefits to auditors and clients. The introduction of AI into auditing practice increases efficiency, accuracy, fraud detection capabilities, improves audit reports and overall audit quality. AI has the potential to change the way audits are conducted in the future, including eliminating sampling, processing more data as evidence, automated evidence verification, proactive control testing, continuous auditing, and rethinking audit standards

As for the automation of the audit process, experts call the most popular computer programs in international practice:

- TeamMate+Audit – a cloud-based tool that provides audit task management, monitoring of the overall audit process for risks and compliance, helps track ongoing issues and determines the adequacy of available staff to generate reports in the required (TeamMate+ Audit);
- CaseWare IDEA – data analysis software that allows you to export information from databases, accounting programs, ERP systems, T&E programs, provides access to audit functions, including problem detection, sampling, generalization, stratification, protects and visualizes data, records analysis steps for possible repetition in the future (CaseWare IDEA);
- Wolters Kluwer CCH Audit Accelerator – provides tools for planning audits, collecting evidence, organizing work folders and documenting audit results (TeamMate+ Audit).

AI is an effective assistant in the work of accounting and financial specialists. In order to meet the requirements of AI and the digitalization of economic processes, to be competitive in the labor market, specialists need to adapt to modern transformations, actively develop new skills, be technically literate, knowledgeable in innovative technologies, be able to apply them in their work and, importantly, develop their potential.

AI can imitate human intelligence, which can be useful in the process of performing the work of accounting and auditing specialists, because automation increases the productivity of cognitive tasks. Innovative technologies help the accounting system to carry out a self-learning process. To do this, the system must have four elements, each of which is important (Fig. 4).

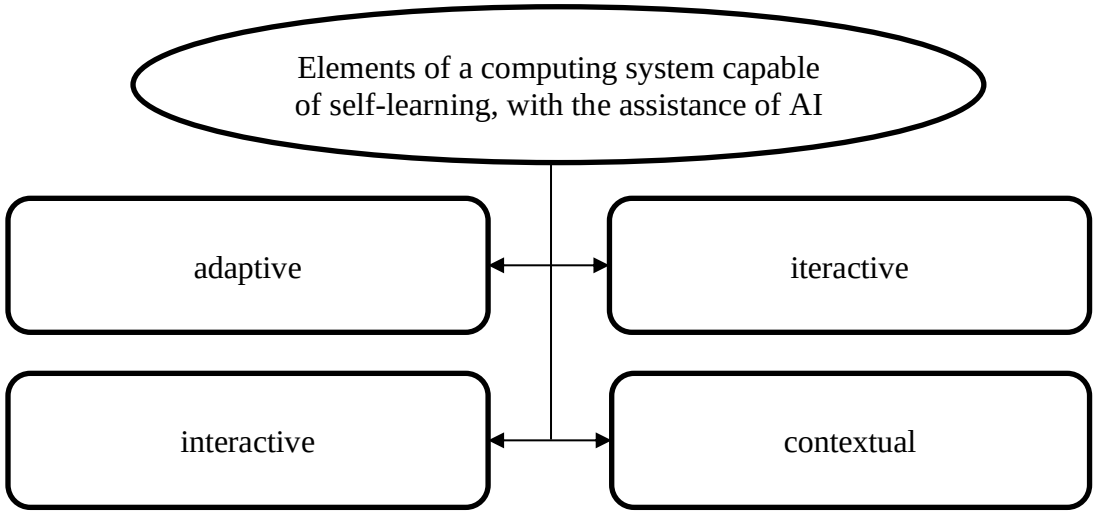

Fig. 4. Elements of the computing system capable of self-learning, with the assistance of AI
Source: authors development

Adaptive elements refer to the system's ability to respond to changes in the collected data. Interactive elements involve interactions between machines and humans to understand human needs. Iteractive elements related to requests from the system for additional data to solve problems. Contextual elements allow us to understand the source and its content.

Thanks to AI, auditors can conduct deeper analysis of data registers, detect significant discrepancies and identify risks, and act faster and more efficiently in response to client inquiries.

Conducting a quality audit promotes effective corporate governance through management accountability and independent assessment of the company's financial statements (Aryani, 2023), and also reduces the risk of legal consequences, fines, and reputational damage, which can lead to a narrowing of the scope of activities due to loss of trust from business partners and customers (Taha, 2023).

By ensuring the accuracy and reliability of financial reporting, audits help protect jobs, investments, and contractual relationships associated with a business. This contributes to the trust and stability of the business environment. Research results demonstrate that artificial intelligence has a positive impact on audit quality by improving systematic changes in the audit process. In addition, AI has demonstrated significant potential in improving audit quality through its ability to assist in the timely detection of fraud. One of the key ways to improve audit quality with the help of AI is to analyze large volumes of BigData. AI-based algorithms can process huge amounts of financial data quite quickly, flagging suspicious financial transactions and potential signs of fraud. This allows auditors to focus on a risk-based approach and allocate resources more effectively (Qader, K.S. & Cek, K., 2024).

A powerful resource for improving the quality of information support for enterprises is Big Data, which makes it possible to assess phenomena and processes in various spheres of public life at a new level.

Big data is an indispensable condition for business development in this period. The study of Big Data enables enterprises to optimize business processes, find more efficient ways to organize production,

and achieve a better level of financial performance. Big data processing allows you to obtain information about weaknesses in the activities of enterprises and determine the causes of their occurrence, as well as understand the conditions for development and growth.

The use of big data brings businesses closer to consumers and helps to improve the satisfaction of their needs by personalizing products and services based on determining customer preferences, demographic parameters and behavioral characteristics.

The definition of the term Big Data dates back to the early 1990s and is associated with John R. Meshey, who popularized the term and therefore went down in history as the founder of big data. There is also an assumption that the primacy in using the concept of Big Data belongs to D. Lane. In addition, some sources cite the name of R. Mugalas and the O'Reilly Media company as the authors of the Big Data idea.

According to experts, Big Data is an array that takes into account structured and unstructured information, as well as a set of methods and tools that facilitate data processing and storage. The analytical company Gartner characterizes Big Data as information assets characterized by large volume, high speed, and diversity, which creates a need for new forms of processing to increase the efficiency of decisions, improve processes, and generate ideas.

The analytical company IDC has formulated an approach to Big Data as a new generation of innovative technologies designed to generate information that is useful for consumers using a significant amount of diverse data. According to Forrester Research, Big Data includes structured and unstructured data of such massive volume that it becomes inconvenient to use traditional databases and software tools to process them.

Since 2015, Gartner has stopped considering Big Data as a popular trend because, according to the company's analysts, it contains a large number of technologies used by enterprises, is to some extent related to other relevant areas, and has therefore become an everyday work tool. However, this does not mean that Big Data is not considered a driver of the development of the information environment, which ensures the conditions for sustainable functioning for enterprises

During the formation and implementation of innovative projects, enterprises feel the need for high-quality information support, and this is due to the need to use huge amounts of data, from which enterprises seek to obtain valuable information to successfully achieve their goals.

Big Data can be characterized by identifying its main features, namely: volume, velocity, variety (Bragazzi et al., 2020). This model was called 3V. The term "volume" implies that big data is measured in terabytes, petabytes, and exabytes. For example, IBS experts estimated the global data volume in 2015 at more than 6.5 zettabytes, for 2020 the forecast data was 40-44 zettabytes, and for 2025 this value should increase 10 times.

"Speed" means that generation occurs at a high speed and determines the corresponding processing rate. It is important to use AI, which automatically finds certain patterns in the collected data and uses them to transform it into knowledge. The property of "diversity" means that data can come from different sources, in various formats.

In the following models (4V, 5V, 7V), new properties appeared that allowed us to deepen our understanding of the essence of Big Data and bring them into line with the current state of the information space and business needs. The 5V model includes additional properties – veracity and value. Truthfulness refers to the level of reliability and quality of data; unreliable data can lead to

misinterpretation of phenomena and processes and, as a consequence, to the adoption of ineffective innovative decisions.

The usefulness of data means that it can yield valuable information that meets the immediate needs of the enterprise. When obtaining valuable information from general data sets, tools that are unique should be used, although enterprises can use standard tools when collecting and analyzing big data.

The 7V model takes into account, compared to the 5V model, two properties – variability (perception variability) and visualization. The variability of data perception implies the variability of the algorithms used to ensure a reliable reflection of the essence of the data during its decoding. Visualization provides the opportunity to better perceive data based on its graphical representation, which should not have a simplified characteristic, but should take into account a sufficient number of variables for effective analysis.

In the modern era of digitalization, Big Data has become an extremely important asset for enterprises. However, despite their undeniable advantages, they also have vulnerabilities that must always be kept in mind (Table 2).

The main principles of Big Data include:

- data localization, which involves the accumulation of data processing and storage operations within the same computing power;
- adaptability of Big Data processing tools to the growth of the volume of information arrays;
- reliability of the tools used due to the use of innovative technologies that minimize the possibility of the impact of failures on the functioning of the system as a whole.

Table 2. Advantages and disadvantages of Big Data

Advantages of *Big Data*	**Disadvantages of *Big Data***
Expand opportunities for interaction with consumers, better meeting their needs by adapting products and services, and ensuring the formation of a new target audience	Incorrect selection and application of big data collection and processing tools can lead to erroneous conclusions
Create conditions for optimizing business processes at the enterprise by analyzing employee productivity and production status	Possibility of threats to the security of personal data and violation of privacy norms
Contribute to improving resource management processes	Likelihood of violation of confidential information regarding specific individuals as a result of the use of data
They serve as a condition for improving innovative activities at the enterprise, which becomes a determining factor in increasing competitiveness.	The implementation of Big Data technology and the creation of the corresponding infrastructure involve significant costs.
Allows you to speed up and increase the effectiveness of management decisions by operating on facts, not assumptions	The need to adapt the Big Data system to the specifics of the enterprise, which requires harmonization of the used tools
They help to identify risks for the enterprise in a timely manner, which makes it possible to apply measures to prevent them and minimize the impact in the event of a risky situation.	Working with Big Data requires IT managers to have new skills that are significantly different from working with conventional data sets.
Provide the opportunity to identify and predict future market trends and, based on this, develop a company development strategy	The threat, in the case of excessive data volumes, of obtaining biased results as a result of processing and analysis

Source: authors development

The outlined principles must be taken into account at all stages of working with Big Data - collection, processing. Data collection can be carried out using a variety of sources - public websites, media resources, social networks, archives, databases, cloud storage, sensor data.

When processing data, the choice of processing method – batch or streaming – is crucial. In batch processing, data is combined into large blocks; this method of processing is appropriate provided by condition of sufficient time interval between the data collection and analysis procedures. When using Big Data streaming processing, sets of small packages are considered simultaneously, which helps reduce decision-making time, but the process itself is quite complex and requires higher costs.

Data cleaning is carried out to eliminate the possibility of errors and avoid the possibility of incorrect data presentation. After data cleaning, the quality of the results obtained increases by removing information that is incorrectly formatted, duplicated or irrelevant.

Big data analysis is one of the crucial stages of working with Big Data, where a well-founded choice of data analysis types and methods is important. When choosing the type of analysis, you can use exploratory, descriptive, inferential, causal or predictive analysis.

Depending on the goals that the enterprise seeks to achieve, the appropriateness of using a particular type of analysis is determined. Descriptive analysis is characterized by assessing the effectiveness of an enterprise's activities over a certain period of time with the ability to compare data at the beginning and end of the period. The essence of exploratory analysis is in the visualization of data analysis, which makes it possible to understand the priority of functions and the relationship between them. The implementation of exploratory analysis can be carried out in two ways: univariate or multivariate.

The application of inferential analysis is based on extrapolating and generalizing data to larger groups based on the study of smaller but representative data sets. In predictive analysis, the reliability of the results obtained depends on the quality of the input data; this type of analysis is characterized by an orientation towards assessing the future, based not on actual data, but on forecast data.

Cause-and-effect analysis makes it possible to establish the relationship that exists between causes and effects, and to provide an idea of how actions or circumstances lead to a certain result.

According to experts, the popularity of Big Data will continue to grow in the coming years, which will contribute to the intensification of development processes in all areas of social life.

According to Statista/Wikibon forecasts, the global Big Data market will reach 84 billion USD in 2024, 90 billion USD in 2025, 96 billion USD in 2026, and 103 billion USD in 2027 (Long live the era of “Big Data”) (Fig. 5).

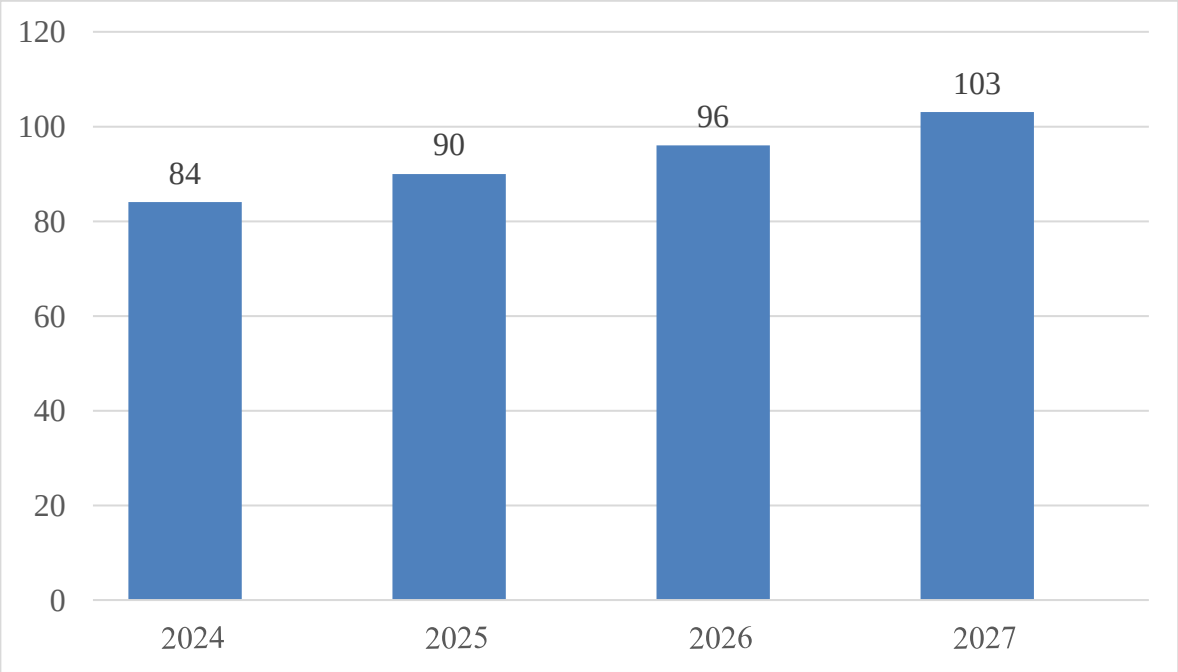

Fig. 5. Forecast volumes of the global Big Data market, billions of USD
Source: authors development

The statement that the use of Big Data is necessary only for large enterprises does not make sense, as the number of medium and small enterprises that realize the benefits of big data and have the opportunity to ensure unhindered access to services for their processing and analysis.

The need for the necessary infrastructure for Big Data is currently being realized in a more affordable form, taking into account the significant growth in computing power in recent times, the reduction in the cost of equipment, and the possibility of using modern cloud services.

However, the main condition for the effectiveness of Big Data remains not only its use in the activities of enterprises, but also the level of validity of the analysis conducted and the reliability of the conclusions drawn. Experts compare big data to oil, which needs to be purified and processed before it can be used again.

Trends in the field of Big Data formulated by B. Marr are of interest, which he identified for 2022, but which will remain relevant in the following years (Key trends in big data).

The introduction of innovative technologies such as machine learning (ML), Big Data, AI, and blockchain into the accounting field has led to significant changes in the professional activities of an accountant (Baduge, S.K. et al., 2022).

These aspects have led to a reduction in errors and distortions of accounting information, increased accounting efficiency and reengineering of accounting procedures, and also contributed to a paradigm shift in the career development of an accounting specialist (Johnson, M. et al., 2021).

Machine learning algorithms can study historical data to identify complex fraud patterns and detect suspicious activity that may go unnoticed through traditional audit methods. This proactive approach allows auditors to stay ahead of fraudulent practices and respond quickly. Additionally, AI-based technologies can continuously monitor transactions and detect potential fraud in real-time using techniques such as anomaly detection and predictive analytics. AI systems can flag unusual or suspicious transactions as they occur, allowing auditors to intervene immediately. This timely detection helps minimize the financial impact of fraud and improves the overall effectiveness of audits (Qader, K.S. & Cek, K., 2024).

The study (Malik, Y., Ojah, H., Al-Shiblaw, G. & Hameedi, K., 2024) aims to study and analyze the role of implementing AI technologies in supporting the predictive properties of financial reporting in the context of Big Data. To achieve the research goal, the authors developed a questionnaire containing 36 questions divided into three separate blocks: in the first block, the questions related to AI techniques, in the second, to determining the value of accounting information in terms of its predictive capabilities, and in the third, to aspects of Big Data measurement. It was distributed electronically to accountants, auditors, and investors on the Iraqi Stock Exchange. About 70 responses were collected from sample participants, who focused exclusively on the practical aspect of the study. The SPSS statistical program was used to analyze the results. The study showed that AI technologies have a statistically significant effect in improving the predictive value of accounting information, and this effect increases in the context of the use of big data. Among the most important recommendations of the study are the need for financial analysts and investors to use AI technologies, as this contributes to the accuracy and speed of analysis and comparisons, which helps to increase the predictive value of information; as well as the need to use and implement analytics and Big Data capabilities due to the fast and accurate processing of the information they provide.

AI systems related to Big Data accumulate specialized software and digital devices for machine learning and developing algorithms capable of solving complex analytical tasks. Therefore, the relationship between AI and Big Data is mutually beneficial, as AI technologies process Big Data with the aim of generating information and transforming it into knowledge that can increase the effectiveness of management decisions (Bragazzi, N.L. et al., 2020). AI also benefits from using this information, as AI studies Big Data to improve awareness and generate predictive information.

Many researchers have concluded that Big Data is important for the functioning of accounting and auditing because it facilitates data management, ensures the rhythm of auditors' work, and generally improves the audit process. Along with this, Big Data methods use neural networks and algorithms to form predictive models that can predict business failure, financial collapse, fraud, stock price changes, etc. (Gepp, A. et al., 2018).

AI-based methods, namely machine learning and natural language processing, can significantly improve audit quality through data analysis, the ability to identify complex fraud patterns, real-time transaction monitoring, and predictive analytics (Noordin, N.A. et al., 2022).

Many factors influence the quality of an audit, including blockchain, AI, the regulatory environment, the size of the audit firm, auditor independence, professional skepticism, and adaptation to the implementation of innovative audit technologies. Moreover, professional skepticism is crucial for audit quality (Janssen, S. et al., 2021).

It is predicted that by 2025, 30% of financial audits will be conducted using AI. Through its integration into audit processes, enterprises can achieve greater transparency, objectivity and reliability in assessing financial statements, which helps ensure a high standard of professional practice and trust from clients. Thus, combining auditor knowledge with AI capabilities proves to be a highly effective way to achieve success in the field of auditing.

Conclusions

The issues outlined in this article are related to the development of the theory, methodology and organization of accounting in Ukraine and the EU countries, the use of technological innovations, in particular artificial intelligence, and other modern technological solutions to improve business management in the context of European integration and globalization, and the improvement of analysis and audit as tools for stimulating the economic development of various business entities.

Benefits of using AI in accounting, analysis and auditing:

1. AI methods help refine forecasts made on the basis of accounting information, which will ensure that management makes effective decisions regarding the financial and economic activities of the enterprise.
2. AI systems help accountants spend their time efficiently when processing and analyzing accounting information, which will allow them to pay more attention to more complex and important tasks.
3. The technical capabilities of AI contribute to the generation of reliable accounting information that will take into account the identified patterns, in particular to improve the financial reporting audit process.

4. Increasing the efficiency of the enterprise management process by processing large volumes of data of various formats, optimizing taxation, etc., to improve the reliability of accounting information due to the advantages of Big Data in volume, accuracy and speed.

Along with the advantages, AI has certain disadvantages that are noted by experts in the information technology industry, namely

1. Without the human factor, AI is not able to create a system that can simplify accounting operations and improve the audit process. Currently, AI performs many simple tasks, but accountants should participate in the final approval of these tasks, because this will allow AI to automatically learn from the tasks it has worked on and include them in the system for future use when solving identical questions.
2. At the moment, AI does not provide the best answers and the field of innovative technologies is still several years away from AI that can be trusted to a large extent.
3. In recent years, large language models such as ChatGPT have made significant progress in their ability to provide answers to complex questions, but they still have certain limitations.
4. Issues of hallucinations, or AI giving false but plausible answers, are a constant problem with AI chat-bots. Therefore, there is a need to require language systems to study and confirm answers from reliable sources before issuing a result. Facts should be compared with established truths and if the answer is even partially inaccurate, the entire source should not be used.

A responsible approach to the use of AI will help maintain a balance between technological progress and ethical standards, ensuring its successful and safe implementation. Thus, the future of accounting, analysis, and auditing is undoubtedly linked to the use of AI systems and the generation of relevant information using AI tools.

References

1. Aryani, D. (2023). The influence of corporate governance mechanisms on financial reporting fraud (A study on property & real estate sector companies listed on IDX in the years 2018-2022), *Indonesian Journal of Economic and Management Sciences*. Vol. 1(3), 389–404. https://doi.org/10.55927/ijems.v1i3.4729
2. Baduge, S.K. et al. (2022). Artificial intelligence and smart vision for building and construction 4.0: machine and deep learning methods and applications, Autom. ConStruct. 141. 104440, https://doi.org/10.1016/j.autcon.2022.104440
3. Bragazzi, N. L., DAI, H., Damiani, G., Behzadifar, M., Martini, M., & Wu, J. (2020). How big data and artificial intelligence can help better manage the COVID-19 pandemic. *International journal of environmental research and public health*, 17(9), 3176. https://doi.org/10.3390/ijerph17093176
4. CaseWare IDEA. URL: http://idea.caseware.com.ua/
5. Gepp, A., Linnenluecke, M. K., O'Neill, T. J., & Smith, T. (2018). Big data techniques in auditing research and practice: Current trends and future opportunities. *Journal of Accounting Literature*. 40(1), 102-115. https://doi.org/10.1016/j.acclit.2017.05.003

6. Hevlych, L., Hevlych I. (2023). Information technologies in accounting and auditing: problems and prospects in the digital economy. *Bulletin of Khmelnytskyi National University. Economic Sciences.* Vol. 3. 40-44. https://doi.org/10.31891/2307-5740-2023-318-3-6
7. Janssen, S. et al. (2021). Auditors' professional skepticism: traits, behavioral intentions, and actions, Behavioral Intentions, Actions (2021), https://doi.org/10.1504/IJIPM.2023.130461
8. Johnson, M. et al. (2021). Impact of big data and artificial intelligence on industry: developing a workforce roadmap for a data driven economy, Global J. Flex. System Management. 22 (3) 197–217, https://doi.org/10.1007/s40171-021-00272-y
9. Key trends in big data analytics that will define the technology in 2022. https://www.bigdatalab.com.ua/news-136/
10. Long live the era of "Big Data" – the time of big data analytics. https://new.minfin.com.ua/ua/kyivstar/bigdata
11. Malik, Y., Ojah, H., Al-Shiblaw, G., Hameedi, K. (2024). The role of artificial intelligence technologies in enhancing predictive ability of financial statements: big data as an interactive variable. *Financial and credit activity: problems of theory and practice.* Vol. 5(58), 136-149. DOI:10.55643/fcaptp.5.58.2024.4490
12. Noordin, N.A., Hussainey, K., Hayek, A.F. (2022). The use of artificial intelligence and audit quality: an analysis from the perspectives of external auditors in the UAE, J. Risk Financial Management, 15(8), 339. https://doi.org/10.3390/jrfm15080339
13. Qader, K.S., Cek, K. (2024). Influence of blockchain and artificial intelligence on audit quality: Evidence from Turkey. https://doi.org/10.1016/j.heliyon.2024.e30166
14. Taha, A. (2023). Internal auditors' independence under workplace bullying stress: an investigative study. *Journal of Islamic Accounting and Business Research*. https://doi.org/10.1108/JIABR-09-2022-0239
15. TeamMate+ Audit. URL: https://www.softwareadvice.com/audit/teammate-am-profile/
16. Wolters Kluwer CCH Audit Accelerator. URL: https://support.cch.com/kb/solution/000239649/000088375?IsNewArticle=True

MANAGING RESISTANCE TO ARTIFICIAL INTELLIGENCE IMPLEMENTATION

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Abstract

This article looks at how to successfully bring Artificial Intelligence (AI) into organizations, something that often gets tripped up by different kinds of resistance like psychological, organizational and ethical. People often resist AI because they're worried about losing their jobs or just don't trust the systems. To deal with this, companies need to really focus on building trust. They can do this by being open and honest, explaining how AI works and letting users have some control over how they interact with it.

On the organizational side, resistance can be tackled by making sure AI projects fit with the company's overall strategy, creating a culture that welcomes new ideas and having good data management and ethical practices in place. Ethical issues, like bias, data privacy and who's responsible when things go wrong, are also big factors in resistance. To handle these, you need solid ways of dealing with ethical problems, making sure things are fair and protecting people's privacy.

It's also important to remember legal stuff, like data protection and transparency laws, which can help reduce resistance. If organizations plan carefully and keep talking to the people involved, they can smooth the way for AI adoption. Plus, education and a supportive environment make everything go much easier.

This article emphasizes that AI systems need to be constantly checked and improved to make sure they're used responsibly. By taking a good look at the psychological, organizational and ethical worries, businesses can manage resistance, get the most out of AI and get everyone on board.

This complete approach makes sure that putting AI in place is good for both the business and society, building trust and acceptance from everyone involved.

Key words: *artificial intelligence, decision-making processes, resistance, deep learning, business management.*

Introduction

For the time being, things are changing fast in the business world and staying ahead of the game is a constant challenge. Business leaders are always looking for new ways to make things run smoother,

make decisions based on data, use Deep Learning (DL) algorithms and boost how much they can get done. That's where Artificial Intelligence (AI) comes in - it's become a real game-changer, with the potential to completely rethink how businesses are managed (Thomason, 2018).

Tech is moving at lightning speed and it's changing all sorts of industries. Healthcare is seeing some huge improvements thanks to digital innovation. As these technologies get better, digital healthcare is offering more and more tools to make diagnoses more accurate, improve patient outcomes and keep better track of patient data over time. AI is a big part of this, especially with methods like Machine Learning (ML) and DL.

These AI methods are used to predict and diagnose all kinds of diseases, especially ones that need a lot of image or signal analysis. AI can also figure out where certain diseases or risky behaviors are more common, making it a powerful tool to prevent health problems. For example, facial recognition shows how AI works using a 2 step process: it takes a facial image, simplifies it and then puts it back together in a human recognizable form.

Machine learning has become really good at looking at medical images because of better algorithms that can automatically pick out important features. These ML techniques can be broken down into three main types: supervised learning (like classification and regression for making predictions), unsupervised learning (using clustering and association to find patterns in data) and reinforcement learning, where the system learns by trial and error or by watching experts.

AI is fundamentally different from how humans think. AI is all about processing data, finding patterns and automating tasks. Human intelligence is much more complex, for instance, it involves things like abstract thinking, communication, problem-solving, learning and understanding. Humans also have emotions like love, empathy, happiness, fear and embarrassment, which AI can't really do yet. Humans also use common sense, creativity, curiosity and imagination when making decisions, using a mix of what they see, remember and feel to deal with tricky situations.

There's a special type of AI called Artificial General Intelligence (AGI) that can create completely new things based on tons of different kinds of data such the text, image, audio, video and even molecular structures and chemical data (Shmatko & Ivchyk, 2023).

This tech works within the broader field of AI, focusing on letting computers learn and make decisions based on patterns in data. DL, which is a more advanced type of machine learning, uses neural networks (like the ones in our brains) to handle huge amounts of information, essentially learning from the data it processes.

Large Language Models (LLMs), which are deep learning tools, can understand and create text that sounds like it was written by some human. They bring together computer science, AI and how we use language (linguistics) through Natural Language Processing (NLP). The NLP lets computers understand and use human language, which is super helpful for anything that needs humans and machines to talk to each other. AGI can also do things like a computer vision, where Generative Adversarial Networks (GANs) make different medical images like slides and scans in order to help doctors diagnose and plan treatments (Kanade, 2022).

NLP is used for things like understanding speech, analyzing text and translating languages which is super helpful for dealing with tons of clinical documents and research data. Thanks to better computers, DL models keep getting bigger and can handle way more complex data. They're even doing better than older machine learning methods. The most common way to train these models is called supervised

learning, where you give the system data (like pictures of skin problems) and tell it what each one is like not harmful or harmful.

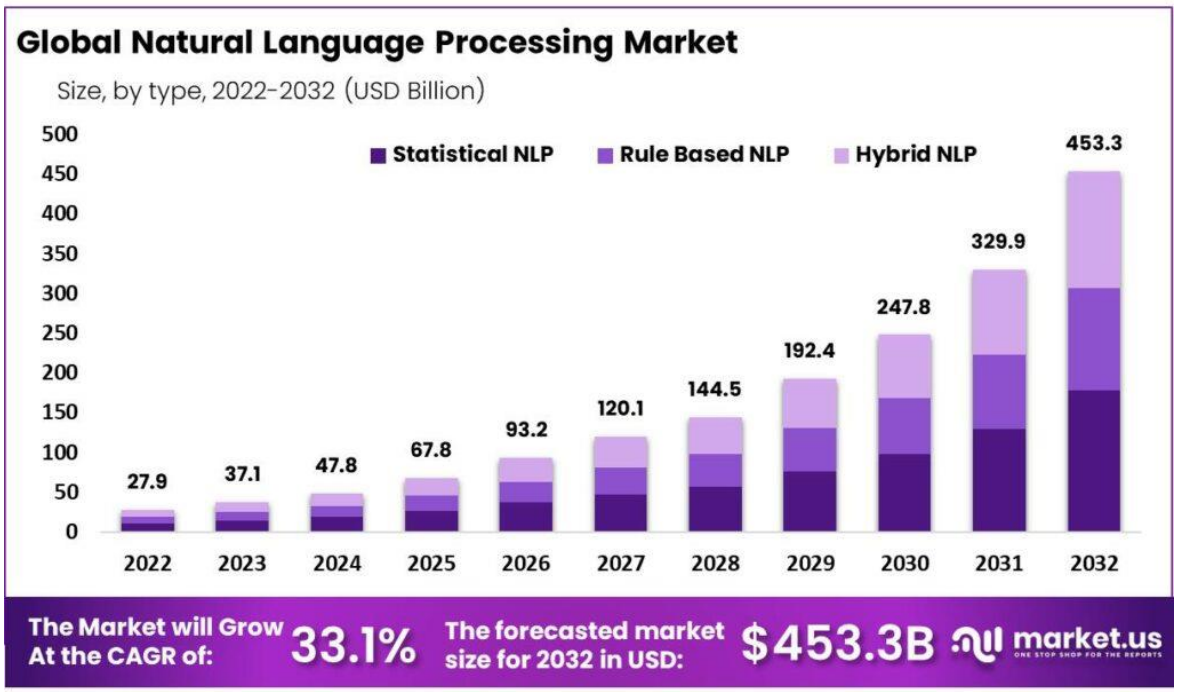

Fig. 1. Global Natural Language Processing Market**.** *Source: Tajammul (2024)*

Another method, called Reinforcement Learning (RL), where the system learns by trying things out or watching experts, has also been really successful in healthcare. RL is especially useful when learning from experts, like in surgeries done with robots.

For example, robots used in surgery can use computer vision and RL to understand images in real time, which makes surgery more precise, helps with navigation and makes it easier to do complicated things like stitching.

There's also something called a Prior-Authorization (PA) automation engine that uses NLP and other methods to figure out how likely different things are to happen which makes decisions much faster.

For instance, this engine might say there's a 90% chance a certain procedure won't help a patient much or it might suggest when a doctor should take a closer look. Then, a medical director would double check the result by hand.

Using predictions and decision-making tools is becoming a key part of personalized healthcare, allowing for surgeries that are tailored to each patient and that can even predict possible problems based on their individual situation. By predicting risks and figuring out the best treatments, these tools make surgery more accurate, help reduce bad outcomes and help patients recover faster. This way of using predictions not only makes surgery better but also shows how important AI is for making medicine more understandable for the humans.

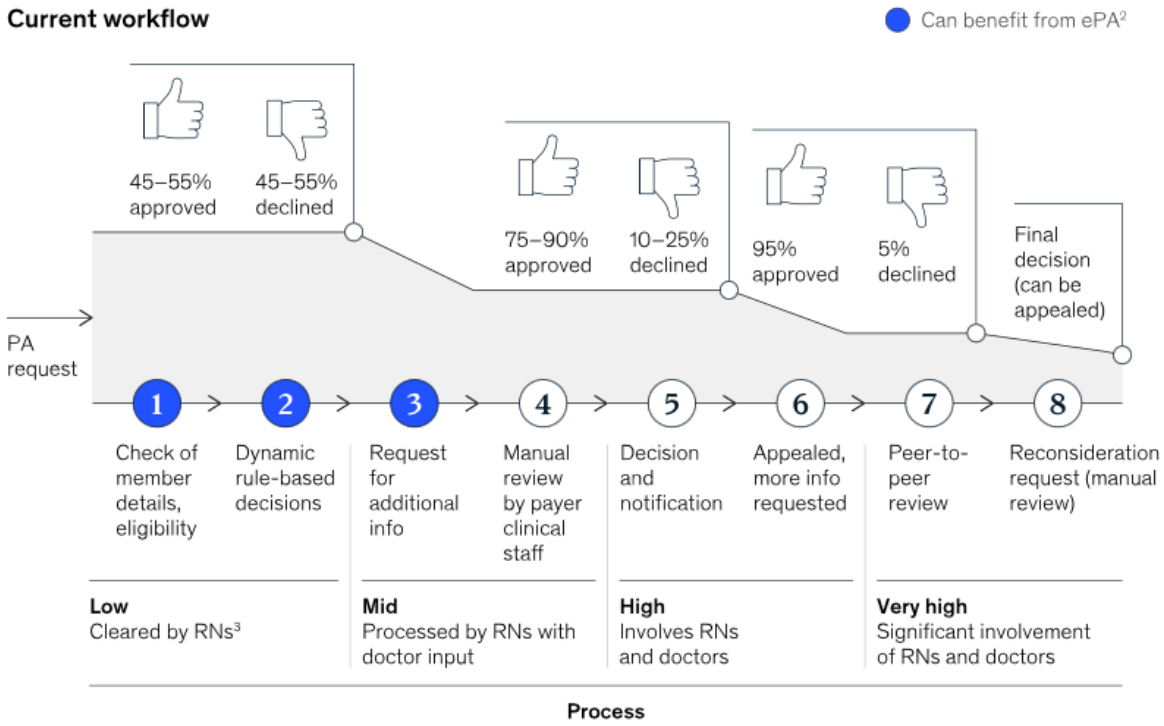

Fig. 2. The current PA workflow with lots of manual steps. *Source: Shahed et al. (2022)*

Once the triage engine figures out how complicated the PA request is, it moves on to the first step: checking if the person is covered by their insurance and what their plan includes. Then, rules that are specific to how complicated the request is will help make the decision. At this point, algorithms make sure that any approvals are really solid, aiming for decisions that are either final or pretty close. Some of these decisions will be checked by humans to make sure things are always getting better.

On the above steps 3 and 6, NLP looks at both organized and less organized clinical text, including notes from the person's medical records (with drug names made consistent to make things easier for the algorithms and to avoid favoring certain brands), along with what the insurance company has reviewed before and any audit notes.

This information is then used by a bunch of algorithms designed to make decisions just as accurately as (or even more accurately than) humans doing it by hand. Moreover, the AI can get even better by using data from when people contact the call-center and send emails or use the insurance company's app if that's available.

ML algorithms usually do a series of calculations on the data they get, going through a few steps: getting the data ready, finding the important bits and then using a model. Getting the data ready is really important for cutting down on mistakes, making things faster and making sure the data is good quality. After that, the model finds the key features in the data and uses them in specific machine learning or deep learning algorithms, which helps the model make better predictions like when it's looking at some image and trying to figure out what this is.

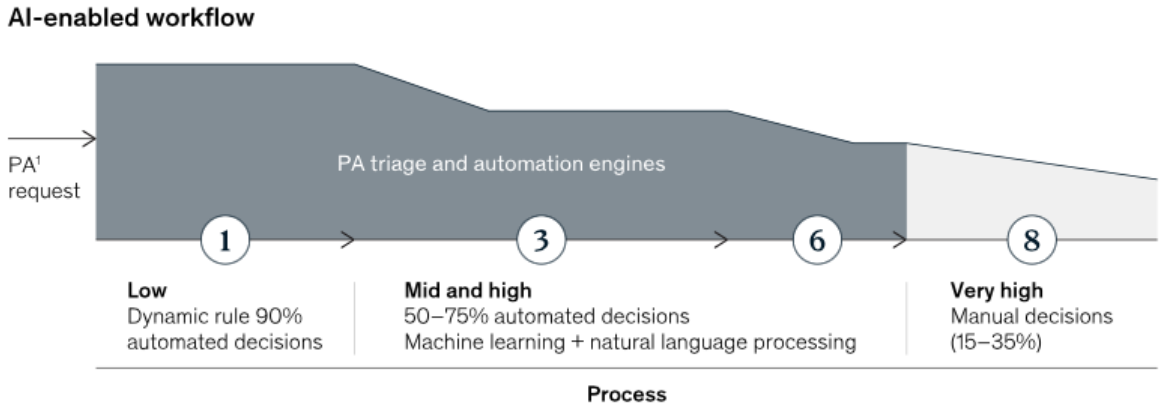

Fig. 3. AI-enabled workflow (Shahed et al., 2022). *Source: Shahed et al. (2022)*

When it comes to medical images, machine learning has gotten really good at doing things that doctors and other medical pros used to do. DL, which is a type of ML, uses a layered structure to process data, kind of like how our brains work with interconnected cells. This lets computers figure out what's important in huge amounts of data all on their own. It means they don't need the people to manually point out the key features the AI learns what's important from the data it's trained on. The fact that we have so much data now along with better computers has made machine learning super popular and a really important tool in healthcare area.

DL has been incredibly effective at recognizing images, doing way better than older models. In the ImageNet competition (where they test how well computers can recognize images), a DL model based on something called CNNs seriously improved, cutting down errors a lot. This really put DL on the map for computer vision. DL algorithms use deep Artificial Neural Networks (ANNs), which are inspired by how our brains are wired. These networks have interconnected neurons in layers and these neurons activate when they get a strong enough signal. In AI, this signal is called a threshold, if the signal is above that level, it gets passed on, creating complex connections that help the model recognize patterns almost as well as humans. This is similar to how signals travel in our brains and has been especially effective for things like image recognition, where DL models can be incredibly accurate at finding patterns or some structures and anything unusual (Nagpal et al., 2019).

But even though AI has so much potential, putting it into practice often runs into a lot of resistance. It's really important to understand why this resistance happens so we can use AI effectively and get all the benefits from it.

Resistance to AI can show up in different ways. People might have trouble understanding it or they might act against it or there might be some problems within organizations. These issues are influenced by a mix of psychological, cultural and ethical factors. If businesses and everyone involved understand these factors, they can come up with ways to reduce resistance, encourage people to accept AI and make sure it's used well in the long run. This article looks at the different types of resistance to AI to help understand why it happens and what we can do about it. Using research and real-world examples from 2019 to 2023, this analysis aims to give leaders the information they need to deal with the challenges of using AI.

Resistance to AI basically means people are hesitant or against using AI technologies in a company or in society. This can come from different things like being afraid of losing jobs and not trusting AI or

having ethical concerns or even cultural differences. Unlike resistance to change in general, resistance to AI often has to do with specific things about AI like how complicated it seems and how it's not always clear how it works and how it might change people's jobs (Barocas et al., 2019).
Cognitive resistance is about the mental blocks that people have when trying to understand and accept the AI. This includes wrong ideas about what AI can do, fear of the unknown and being skeptical about whether it actually works. AI often brings changes that are complicated and not well understood by most people even by those working in related fields. People normally don't like changes that make things uncertain. This may be because of our instincts, usually, we tend to see anything unfamiliar as the possible threat.

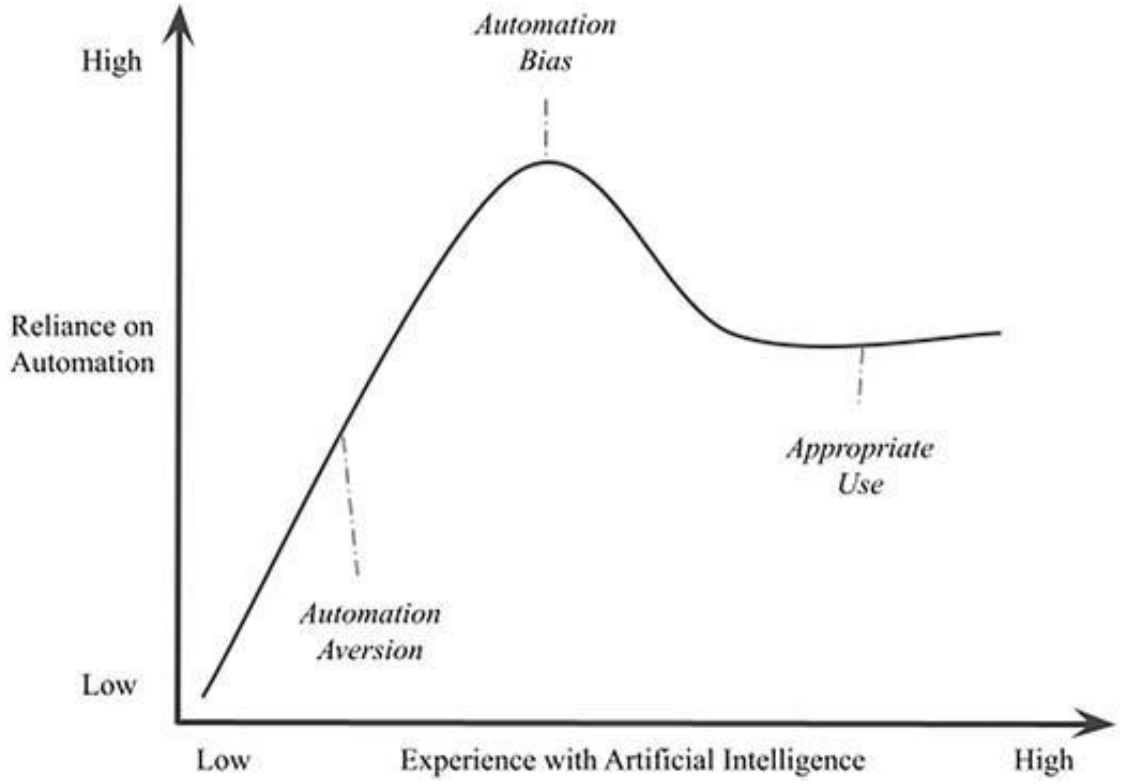

Fig. 4. Bending the Automation Bias Curved**.** *Source: (Horowitz et al. (2024)*

When AI systems give recommendations or change how things are done, it can feel unsettling or even scary for some people. This is because these systems often seem like black boxes that they give you some result but you don't really know how they got there. This lack of understanding makes it hard to trust and accept the technology in general. One of the main reasons people resist AI is the idea that it might take away our control. For example, when AI starts making decisions that affect our lives like who gets hired or what medical diagnoses are or what financial advice we get that person can feel like their freedom is being taken away. Humans also resist AI because it feels like it's "invading" areas that they used to handle. This can make people feel helpless or frustrated when decisions that used to be clear and under human control suddenly become mysterious in case of basing on some algorithms.
Persons can focus on the bad news about AI, especially if it matches what they already think or fear about new technology. For example, stories about people losing their jobs or privacy being invaded or

AI messing up get a lot of attention. Which makes those fears even stronger. This is made worse by something called confirmation bias, where people look for information that only confirms their doubts about AI. This can make the resistance even stronger, because humans only see evidence that supports their negative view. From other side, some resistance comes from ethical worries. Many people aren't comfortable with machines making big moral decisions, especially in subjects like law enforcement or the military and healthcare. They also try to apply human ethics to machines. Moreover, the person can expect AI to follow his moral rules but machines don't necessarily think the same way we do which causes confusion and resistance (Bond, 2024).

The public, especially experts in certain fields, might resist AI because they feel like it's threatening their expertise. They might think that AI is taking over their jobs, making their skills less valuable. For example, lawyers or doctors and analysts might push back against AI because it seems to be moving into their professional territory. Individuals are usually proud of solving some tough problems, so the idea that an AI could do it better can make them defensive and resistant. By the way, the people are also skeptical about how reliable AI is. Stories about AI making mistakes, being biased or making wrong predictions make the resistance stronger because they show the limits of AI compared to human judgment. It's also confusing when they don't really understand how AI learns or makes decisions. If you don't know how the algorithms work, it's easy to assume that AI is going to make mistakes that can have serious flaws.

To reduce this resistance the company can give clear and easy to understand information about how AI works and what it means for people and they can address worries about job security. Creating an open and learning environment helps the person to feel more comfortable with the changes that AI brings. Also, explaining on some trainings, how the algorithms work and making AI processes more transparent and showing how decisions are made can help reduce resistance. Introducing AI step by step and in less sensitive areas lets individuals to get used to it and build the trust to AI. Sharing examples of how AI has been helpful in jobs or other areas could also help change negative views.

Resistance to AI can also show up in people's actions. This can be active resistance, like refusing to use AI tools or passive resistance, like putting off using them or even messing up AI projects on purpose. Many employees resist AI because they're afraid it will make their jobs unnecessary. Research shows that employees often resist AI when they think it might replace what they do or take away their decision-making power. For example, in healthcare, some people worry that AI diagnostic tools might mean fewer jobs, especially if those tools get more accurate over time. This fear can make employees resist using AI tools even if they could be helpful (Chen et al., 2020).

People also resist AI because they feel like they're losing control. Employees might resist AI if they think it reduces their freedom with their professional judgment. For example, in healthcare, doctors sometimes worry that AI recommendations might limit their ability to make their own decisions or that relying on algorithms can make patient care less personal. This point might be especially strong for professionals who are making their own decisions, as AI can feel like an entry on their expertise.

There are also some ethical concerns. Like employee might not be comfortable with AI making some decisions that are ethically not understandable, especially if it's not clear how those decisions are made. In healthcare, for example, professionals might worry that using AI for diagnoses and treatments could make it unclear who's responsible if something goes wrong. A lot of persons are also worries about

the black box nature of AI algorithms which can lead to mistrust and hesitation about using the technologies (Greenhalgh et al., 2017).

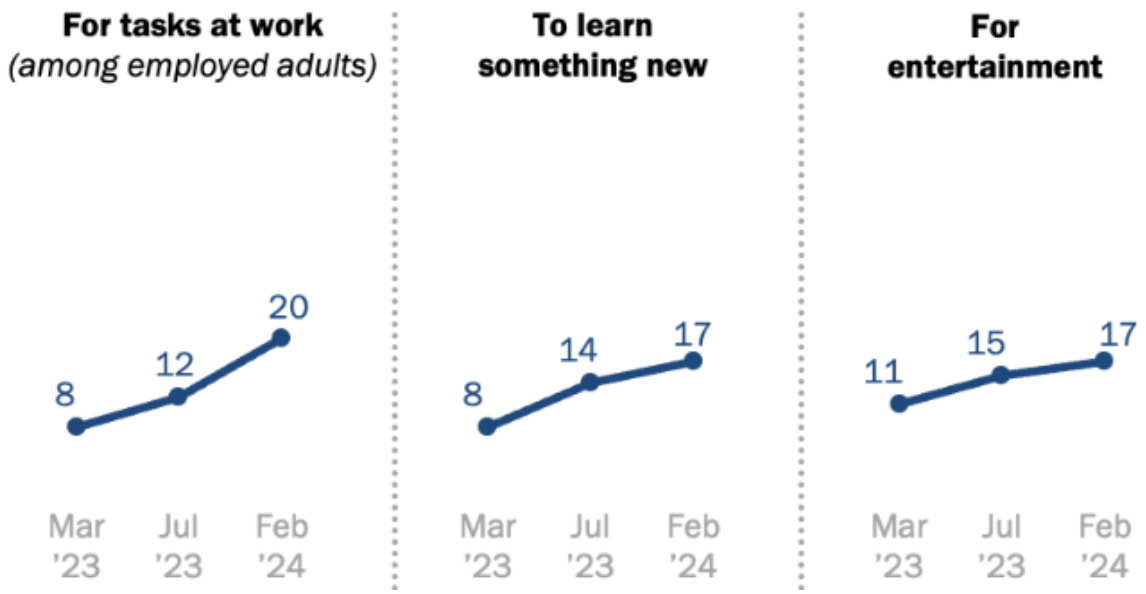

Fig. 5. Share of employed Americans who have used AI for work**.** *Source: Valchanov (2024)*

The people also avoid some new techonlogy because it's hard to adjust. Using new AI often means learning new skills or changing how you work and getting over feeling unsure about using fancy tools. For example, if doctors or nurses have to start using ML in their daily work they might have to understand computer results, which can be very huge and make them resist just because they don't get good training (Kaplan et al., 2019).

Another thing that makes people resist is being anxious about working with AI. Some worker may feel not comfartable about the idea of working with smart systems and worrying that AI will become better than he/she or change how things work at his/her job. This fear is even stronger in jobs that involve complicated decisions and dealing with people's feelings like in healthcare. There, the presence of AI might make professionals feel like they're not good enough anymore or even that they're becoming obsolete. Even if AI is only meant to help them (Floridi et al., 2018).

Dealing with this kind of resistance at work needs a few different approaches that address what employees are worried about and build the trust to AI and not forget to get them ready for the changes and for the new technology. One important thing is open communication within the company. It should clearly explain why they're using AI and how it would affect their job. This can be helpful to reduce their fear. Getting employees involved in using AI, especially early on when planning and testing, can also reduce resistance because it makes them feel like they have some control over the process.

Giving people the right training/courses and helping them in developing som new and modern skills makes them feel more confident in themselves and be less threatened by AI. Especially if they see it can make their jobs better and not something that takes them away. You can also ease worries about ethics and who's responsible for what by having clear rules about how AI is used in the company. This makes workers feel more secure about AI’s decisions.

Showing examples of how AI has been helpful in similar industries or in test programs of their job can also help them to understand how it can be useful in their real life. Which builds excitement and reduces their fear of the new technology. Creating a culture where everyone is always learning helps employees to adapt and verify that AI is a way to grow both personally/professionally sides.

And last but not the least - introducing of AI slowly and providing good support like technical help or having dedicated AI champoins on their team. The idea is to give the worker time to adjust at a comfortable pace despite usual project's hurry. All of the things help minimize the resistance and make the transition smoother, creating a more supportive environment for using AI.

Resistance can also come from problems within the company's itself like a lack of support from leaders ornot enough training or just being stuck in old ways of doing things. This is often because of deep-seated worries within organization. Both about how things are structured and the company's culture. This resistance can shed the light on not wanting to spend money on AI, being afraid of job losses or not having everyone on board. Some of the main reasons for this kind of resistance are trouble changing how things are usually done or how complicated it is to add AI to existing systems and how it might change who has power in the company. The champions are really important for dealing with these points by creating some culture/trainings where the team is open/ready to change. Where everything is up to maximum transparent and where the crew works together. In this kind of culture AI is seen as a helper not a replacement for them.

To show how resistance to change affects and how ready a company is for AI, we came up with a model that provides the importance of good leadership and high performing work systems. The mentioned below model suggests that how much worker can resist the change can and how it affects the readyness for AI. With good leadership whick helps to manage the resistance and good work systems make it easier to adapt for the whole squad. It uses H1-H5 variables, let's look deeper.

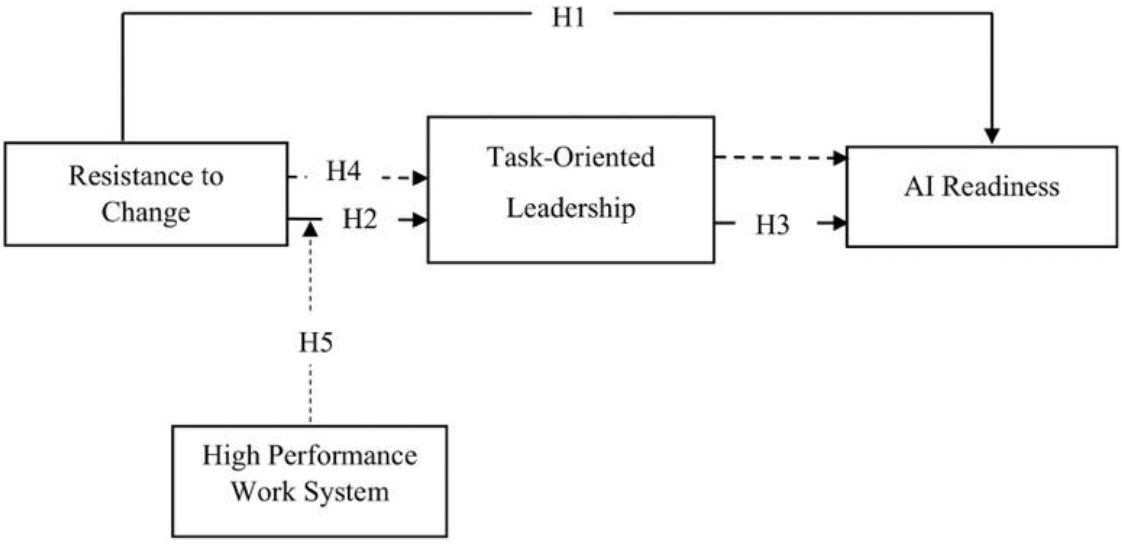

Fig. 6. Research framework for resistance to change**.** *Source: Cai et al. (2023)*

So, H1 says that resisting change really messes with how ready a company is for AI. H2 says that resistance to change also has a big impact on how leaders lead. H3 says that good leadership helps the

organization gets ready for AI. H4 says the leadership helps manage the connection between resisting change and getting ready for AI. And the las one - H5 says that having a good work system makes that connection even stronger.

This whole idea helps us understand how resisting the change and different leadership styles and how the company can organize all the working aspect together in order to affect the company's readyness of using the AI.

Like the example again, in healthcare, using AI for finding diseases can meet some resistance from the medical staff. Normally, they should be worried about losing their jobs. For instance, some radiologist is afraid that the AI could take over his role in looking at medical results. Even though there's proof that AI can make diagnoses more accurate. The truth si the idea that it could make some jobs unnecessary has caused some pushback from the worker. This shows that champions need to make it clear that AI tools are there to help and not fro replacing his/her expertise. As a result, the healthcare's employees can give better care and faster provide the diagnose. And to highlihgt - not feel like they're becoming less valuable (Bouly, 2024).

Another example is the current finance world where people often resist AI because there are really strict rules about keeping data private. AI needs huge amounts of data to learn and provide the correct prediction. For sure, it might be sensitive customer information, who cares about it? Worries about the data leak and the risk of getting fined can make people hesitant. Assuming that many organizations are concerned about AI accidentally breaking data privacy rules. This can slow down AI adoption in financial services, where keeping data safe and following the rules is super important. To deal with these points, you need to be open about how AI is being used and make sure the systems follow the rules and put strong data security measures in place.

The other view of the company is manufacturing. Many organizations have troubles getting AI to work with their old systems/approaches. Which might not be compatible with the modern AI algorithms. This resistance comes from how complicated and expensive it is to upgrade the old equipment to work with latest technology like AI. Many manufacturers think about how much it would cost upfront and whether it will disrupt things while they're switching over. The questions make them hesitant to use the AI in their products. To fix this, we need a plan of introducing AI gradually and maybe use some systems that let AI work alongside the older systems for some itme instead of replacing them entirely in one moment (Bhatt, 2024).

Dealing with the resistance to AI within a company is really important for leaders to make sure AI is used smoothly. Resistance often comes from things like being afraid of the unknown things. Feeling like the job is threatened, not trusting AI, having troubles in adapting to the technologies.

Talking openly about the pros and goals of using AI is key to deal with the resistance. Leaders should clearly explain how AI can make the company run better. Not too forget to mention that the aim is to improve their efficiency and create some new opportunities/tasks instead of just replacing them. Making it clear that AI is there to help people do their jobs better can reduce uncertainty and make people feel like they're part of the process. Being open about how the AI systems are being developed and tested and used also assists build trust among the workers in the company.

Getting everyone involved early on, mainly the people who will be using the AI tools can also minimize the resistance to changes. Because it would make them feel like they have some control of the changes. This can also help find any points the people have. So they can be addressed before AI is

actually used. For instance, doing surveys or talking to groups of employees can give us some insights into the concerns and give us a chance to clear up any confusion.

Moreover, the resistance to AI is also often about worries about ethics, fairness and visibility. The company needs to sort out the concerns by making sure AI systems are developed and used responsibly with respect to their private data. This means making sure the systems aren't biased. In this way, it should be clear how they make decisions and that they're designed to protect security. Having various teams working with AI can also support and fix any biases that might appear in the AI models. Introducing AI gradually can also help ease resistance. Starting with small tests or using it in limited ways lets employees experience AI in a manageable way and see how it affects things before it's used everywhere. This gives the company a possibility to identify any problem and adjust the AI as needed. The other aspect that organization can encourage applying the innovation and constant learning of their workers. It definetly can make much easier for people to accept the AI. When employees feel like the company values new ideas and helps them develop their new skills - they're less likely to resist change and more happy to introduce the AI in their routine. By stimulation of trying new things like AI and being open for the new technologies would build resilience against resistance to AI.

To really deal with resistance effectively, it's important to understand the psychological reasons behind it. There are a few key things that make person hesitant to embrace AI. For example, one of the biggest worries is the panic of losing jobs. Humans think that automation and AI might replace them making their jobs unnecessary. Normally, AI has lots of good things to offer like making activities more efficient and leading to the new innovations. Also, it should make individuals anxious about their jobs, which makes them resist using these technologies.

Industries like manufacturing, retail and even knowledge based areas like finance and healthcare are using AI more and more for automation which can lead to worry that jobs in these areas will disappear (Brynjolfsson et al., 2014).

Lots of employees may feel like AI is changing so fast that they can't keep up. People who don't have a chance to get retraining or learn new skills might feel left behind their knowledge and see the AI as a threat to their job. Based on other scientific reaserchears can make it harder to use AI because the persons might resist using AI or even slightly adding them to their work. Obvuous, because they're afraid of being replaced by AI one day (Frey et al., 2017). So raising the trust to AI and being open about what it can do can help reduce these fears (Zogaj et al., 2020).

Employees might also be afraid that AI will take away their control over making decisions to make them feel powerless or more useful. When the AI takes tasks that humans normally do they might feel like they're losing their independence and influence at work (Dastin, 2018). To deal with this, organizations must give their workers a couple of chances to learn appropriate new skills. All these steps can feel more secure helps them instead of threaten. Important to clarify open about how AI will be used and what kinds of tasks it will automate. They should also be involved in designing and using AI systems and their opinions matter and as a result - reduce their nerves of the changes.

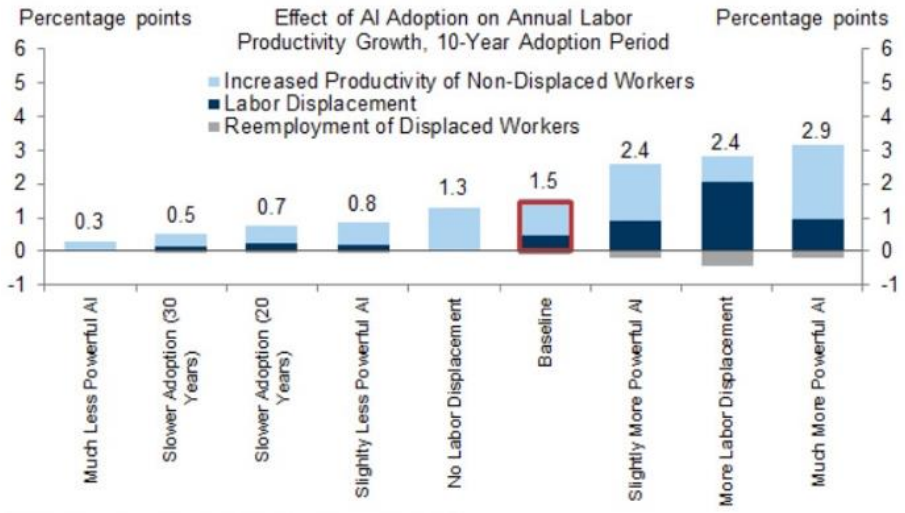

Fig. 7. Estimation of boosting aggregate labour productivity**.** *Source: Pethokoukis (2023)*

As we can see the huge factor of applying the AI by the employees is the trust. Basically, it's about how confident users are that AI is reliable, accurate, fair. People need to believe that it may give trustworthy results and work safely with the correct ethical decisions. Otherwise, they're much more likely to resist or reject the new technology even if the AI would make things more efficient and productive.

One of the main things that can grow the trust in AI is how visible and known it is. Persons are more likely to trust AI if they can understand AI's decisions. This is principally important for some big decisions in the subjects like healthcare, finance or law enforcement. In the areas where people need to know how AI decisions affects correctly. If the AI system is like a black (you can't see how it works) - the employees might be uncomfortable relying on AI. Even more, they can worry that the AI could lead to biased, unfair or wrong absolutely wrong decisions (Lipton, 2016).

How reliably the AI system? How consistently and accurately does AI perform its job? It's another pretty big point to discuss. AI systems can often make mistakes or do unpredictably. Or just don't meet the expectations. It can slow down the trust to the AI and make the people hesitate in AI's value. Showing how well AI works in real world situations and testing it carefully must help grow the confidence in them. In the future, no doubts, the AI tools will prove they're accurate and reliable (Lee et al., 2004).

Trust in AI is also affected by concerns of some ethical issues, mostly the chance that AI tools might keep existing biases going or even make them worse. The AI programs are normally trained on huge amounts of data that might have intolerance in them and these points can appear in the decisions that the AI makes. It raises some questions about fairness, responsibility, openness in the tools. Individuals might oppose AI if they think it's unfair. Making sure AI programs are designed to minimize the favoritism and promote fairness (O'Neil, 2016).

Sometimes, employees might belief AI too much or not enough. It can lead to wrong expectations. If people don't trust the AI enough, they might ignore its recommendations or even if the tool is actually pretty good. This uncertainty means they miss the benefits of AI. On the other hand, over trust happens when the person has too much faith in AI. And without any verivicaton follows its advice. For example, if someone beliefs a recommendation service too much - it could lose money in case of trading on the

stock exchange. This over belief would quickly turn into dis belief. To make sure AI is used effectively, the person who makes the product need to constantly work on keeping user belief at the high level. But it takes time and effort to aid the humans to understand what the AI can and can't do, af of today. AI tools are based on possibilities and can sometimes make mistakes. It’s not ideal and the results must be double checked by the human. Belief isn't about the system being perfect - it's about being honest. And admitting some mistakes and fixing them in time. The end user needs to be able to judge how much they can trust that the AI says. But definitely verify the AI’s response and only after that it’s own decision.

Very important two points of building belief in AI - explain and control. If the person doesn't understand how an AI system works, it can't believ it. Explain makes sure people understand how the system works. Clear explanations aid them have the right expectations. Which definitely aids them decide how much to trust the AI's advice. While detailed explanations can be complicated - it's important to make them as easy to understand as possible.

Being in control is also really important for building trust. Individuals are much more likely to trust the AI if they feel like they can have influence on how it works. Or at least, possibility of infulence. Letting users change data, choose what kind of results they want, ignore recommendations and fix mistakes by giving feedback makes them feel more in control. This not only makes them belief the AI more but also makes them want to keep using it. So, users must be actively involved in the decision-making process in oder to have more trustworthy relationship with the AI.

For example, humans often pay more for brands they trust instead of buying cheaper things. Comparably, when we go to the doctor, we expect to be able to trust their diagnosis. Persons tend to keep their savings in banks they trust and only buy things from websites they feel safe using. We even choose safe places for our kids to play and relying on people we trust to keep them safe.

Without the belief, even simple things would be really hard. Trust is essential for things to work. Trust is basically being willing to take a chance because you expect something good to come out of it. In business, it means believing that the other person will act honestly. When there's a lot of trust - people talk openly and treat each other fairly, work together in good faith. Being transparent is the. Being clear about who's responsible for what is also crucial - it stops people from blaming each other. A good team, whether it's made up of people or a mix of people and AI, is built on trust (Kore, 2023).

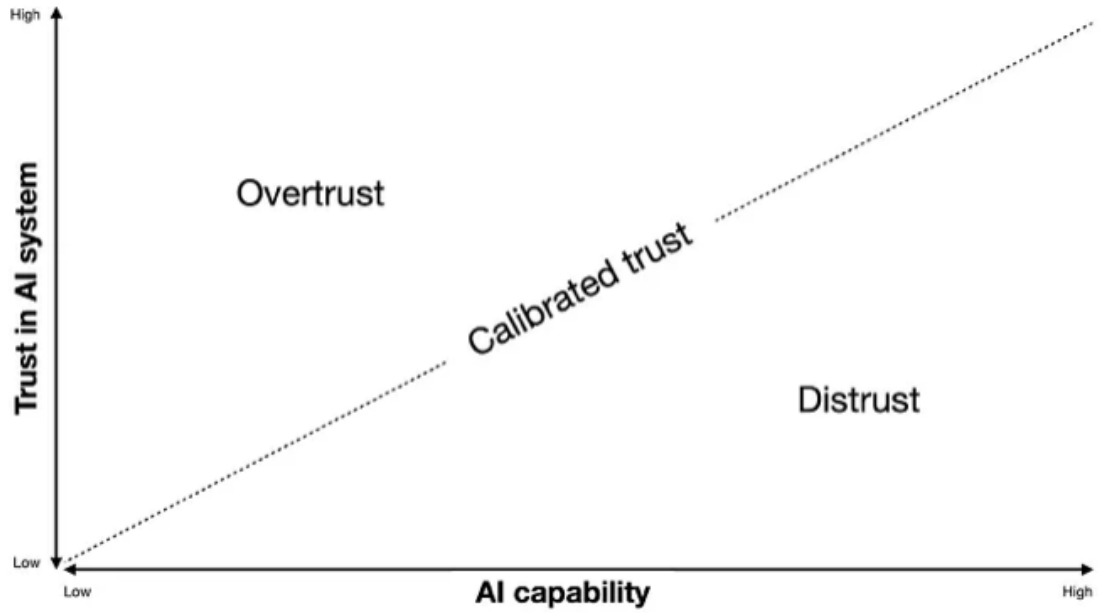

Fig. 8. Trust calibration**.** *Source: Kore (2023)*

What persons believe about AI is also tied to worries about data privacy and security. Since AI systems often use huge amounts of data, including personal and sensitive stuff, users need to be sure that their data will be safe from leaks, misuse or unauthorized access. If human feel like AI is a risk to their privacy or security, they might be hesitant to use it. Companies need to have strong security measures in place and clearly explain how they protect user's data to build trust in AI (Liu et al., 2019).

The culture where AI is used also important in how much people trust it. In some cases, people might be more open to new technologies, while in others, they might be really hesitant about the AI. Like how much value is placed on human control versus automation (Dignum, 2018).

Ethical and accountability issues in AI are other really important points. As these technologies keep affecting different areas of our lives. For example, AI systems often show unfairness that were in the data they were trained on, which can lead to unfair results, especially in sensitive areas like hiring, lending or law enforcement. To fix the points we need to diverse datasets and fair algorithm design. The risks from unfairness in AI are serious and definitely needs urgent attention. As AI becomes more and more a part of how society works the chance of harm from biased decision-making gets bigger. It means unfairly treating people or groups based on things like race, gender or even social class. It would lead to unfair practices in many areas, like jobs, loans, law enforcement, healthcare.

One example is a study by researchers from MIT and Microsoft that showed big racial and gender biases in facial recognition software from major tech companies. These systems were much less accurate at identifying women and people with darker skin compared to men and people with lighter skin. These kinds of mistakes can have serious consequences, especially if these technologies are used by the police, which could lead to unfairly targeting certain groups.

Another example is the COMPAS algorithm, which is used a lot in the US criminal justice system to predict how likely someone is to commit another crime. A 2016 investigation by ProPublica found that this algorithm unfairly flagged Black defendants as being at higher risk of reoffending compared to White defendants with similar backgrounds. This point keeps existing inequalities going, making things even more unfair in sentencing discrimination in the justice system (Angwin et al., 2016).

Because of the points, governments and organizations have started taking steps to reduce the unfariness in AI. For example, California passed a law in 2020 that requires companies to document how well their facial recognition systems work for different groups of people before they can be used by law enforcement. Mostly, for black people. This stimulates the transparency and aims to make sure people are held responsible, pushing for fairness in how is using AI. To fight it in AI, we need to work on making datasets more diverse, making algorithms easier to understand and getting different champions to work together in order to stop the tools from making existing disproportions worse (Benneh, 2023).
It's clear that AI needs so much data it can create some big privacy risks. We need stronger direct about how the data is handled and ways for end users to give their permission to use their data to reduce these risks. It’s important to protect the rights to the AI model and how it works. Also keep the training data private, mainly in sensitive areas. Keeping data safe in AI systems means having ways to prevent both the models and the data they were trained on from being exposed, making sure the data is good quality, accurate and only accessible to the right person.
AI systems need to protect the privacy and the data. This includes keeping both user provided data and data the system creates safe. We need clear rules about who can access the data and when. Following laws like the GDPR in the EU/UK can make these processes official (Butterworth, 2018).
When dealing with the data of doing something called a Data Protection Impact Assessment (DPIA) is the standard way to check the risks related to data is used in AI systems. This is even a legal requirement in some places, like in the EU/UK. DPIAs help organizations find potential problems in how they manage data, like the risk of data poisoning where training data is deliberately changed to make the model do harmful things. These evaluation make sure that data protection concerns are dealt with properly, keeping things legal and making sure AI is used ethically (Table 1).
Verifing the security of AI models are means understanding how much access potential hackers have. From knowing almost nothing to seeing everything. And also figuring out when the model is most vulnerable (like when it's being trained or used to make predictions). In addition, you have to think about what kind of attacks might happen, from people just being curious to people trying to do harm. The risks include attempts to copy the model's or create fake versions or mess with how the model works (De Cristofaro, 2020).
So, to sum it up, using AI is changing industries, but humans often resist it. To get through these problems, companies need to take a few different approaches that deal with the psychological, organizational and ethical points.

Table 1. UK Information Commissioner's Office (ICO) qualitative rating for data protection (OECD, 2023)

Colour code	Internal audit opinion	Definitions
Green	High assurance	The organization has good systems and procedures in place that do a solid job of making sure they follow data protection rules. The audit showed there are only a few small things they could do to make things even better. So, they don't really need to do anything major to reduce the risk of not following data protection laws.
Yellow	Reasonable assurance	The company can be reasonably confident that their tools and procedures are helping them follow data protection rules. However, the audit pointed out some specific areas where they could make things even stronger and further reduce the risk of breaking data protection laws.
Orange	Limited assurance	The organization can't be very confident that their current systems and procedures are doing a good enough job of helping them follow data protection rules. The audit found some significant areas that need improvement to reduce the pretty big risk of not following data protection laws.
Red	Very limited assurance	The company has very little confidence that their current tools and procedures are enough to make sure they follow data protection rules. The audit showed a really big risk that they probably won't be able to meet data protection requirements with how things are now. They need to take urgent action right away to improve things and fix the problems that were found.

Source: authors development

They often resist AI because they don't trust it. This is because they don't understand how it makes decisions and they're worried about unfairness or some mistakes from AI's side. To grow the believe - we need to make things clear with trainings/explanations and give users some control with interacting with AI. The open systems build confidence and accountability, making sure the work is ethical. The fear of losing jobs is also a big problem. Companies should show how AI can help them do their jobs better. Retraining programs and clear communication from AI's champions can help calm the worries. Resistance within organizations often comes from being stuck in old ways of doing work and not being ready for AI or even not having AI strategies. Leaders need to create a trend of innovation and make sure data is managed well. Not to forget, that AI projects fit with the company's overall plans to make all the things run smoothly.

Also, ethical concerns, mainly about data privacy and unfairness in the AI's algorithms. It means we need to have a visible way of managing the moments. Doing data protection checks and making sure the organization follows the rules can reduce risks. Also it makes sure people are held responsible. Talking clearly with everyone involved employees and customers is really important. Working together on decisions and being open about things can aod everyone agree on the points and reduce resistance of the changes. Using AI isn't a one time job - it's definitely an ongoing process. Regular checks, feedback, surveys and training would help either the employees or the company to increase productivity and income.

References

1. Thomason, R. (2018). Logic and Artificial Intelligence. In Zalta, Edward N. (ed.). Stanford Encyclopedia of Philosophy. Retrieved from https://plato.stanford.edu/entries/logic-ai/
2. Shmatko, N., Ivchyk, V. (2023). Unleashing the capabilities of artificial intelligence in managing businesses. Retrieved from https://scholar.google.com/scholar?oi=bibs&hl=en&cluster=1366031303130878285
3. Kanade, V. (2022). Narrow AI vs. General AI vs. Super AI: Key Comparisons. Retrieved from https://www.spiceworks.com/tech/artificial-intelligence/articles/narrow-general-super-ai-difference/#:~:text=Narrow%20AI%20is%20focused%20on,demonstrates%20intelligence%20beyond%20human%20capabilities
4. Tajammul, P. (2024). Natural Language Processing Statistics 2024 By Tech for Humans. Retrieved from https://scoop.market.us/natural-language-processing-statistics/
5. Shahed, A., Vipul, K. (2022). AI ushers in next-gen prior authorization in healthcare. Retrieved from https://www.mckinsey.com/industries/healthcare/our-insights/ai-ushers-in-next-gen-prior-authorization-in-healthcare
6. Napgal, C., Ram, S. (2019). A Performance Evaluation of Convolutional Neural Networks for Face Anti Spoofing. Retrieved from https://arxiv.org/pdf/1805.04176
7. Barocas, S., Hardt, M., & Narayanan, A. (2019). Fairness and Machine Learning. Retrieved from fairmlbook.org
8. Horowitz, M., Kahn, L. (2024). Bending the Automation Bias Curve: A Study of Human and AI-Based Decision Making in National Security Contexts. Retrieved from https://academic.oup.com/isq/article-abstract/68/2/sqae020/7638566
9. Bond, M. (2024). How Cognitive Biases Impact AI Adoption: What Every Business Leader Should Know. Retrieved from https://hackernoon.com/how-cognitive-biases-impact-ai-adoption-what-every-business-leader-should-know
10. Chen, H., Li, L. (2020). Journal of Management Analytics. This study examines AI adoption in complex professional environments, such as telecoms and healthcare.
11. Greenhalgh, T., Stones, R., & Swinglehurst, D., et al. (2017). Health and Technology. Discusses technology integration challenges in healthcare.
12. Kaplan, A. M., & Haenlein, M. (2019). California Management Review. Explores how AI reshapes job functions and the organizational role of employees.

13. Floridi, L., Cowls, J., Beltrametti, M., et al. (2018). Minds and Machines. Analyzes the ethical framework necessary for implementing responsible AI.
14. Valchanov, I. (2024). The Resistance to AI: An Inevitable Societal Fracture? Retrieved from https://team-gpt.com/blog/the-resistance-to-ai/
15. Bouly, J. (2024). Four critical strategies for sustainable gen AI adoption. Retrieved from https://www.mckinsey.com/capabilities/people-and-organizational-performance/our-insights/the-organization-blog/four-critical-strategies-for-sustainable-gen-ai-adoption
16. Bhatt, A. (2024). The risks and ethical implications of AI in financial services. Retrieved from https://www.fisglobal.com/insights/risks-and-ethical-implications-of-ai-in-financial-services
17. Cai, L., Farshan, S. (2023). Consequence of Resistance to Change on AI Readiness: Mediating–Moderating Role of Task-oriented Leadership and High-Performance Work System in the Hospitality Sector. Retrieved from https://journals.sagepub.com/doi/full/10.1177/21582440231217731
18. Brynjolfsson, E., & McAfee, A. (2014). The Second Machine Age: Work, Progress and Prosperity in a Time of Brilliant Technologies. W. W. Norton & Company.
19. Frey, C. B., & Osborne, M. A. (2017). The future of employment: How susceptible are jobs to computerization? Technological Forecasting and Social Change, 114, 254-280.
20. Zogaj, S., Hanelt, A., & Kolbe, L. M. (2020). Adoption of artificial intelligence in organizations: The role of organizational culture. Proceedings of the 53rd Hawaii International Conference on System Sciences.
21. Dastin, J. (2018). Amazon scraps secret AI recruiting tool that showed bias against women. Reuters.
22. Pethokoukis, J. (2023). Why Generative AI Could Have a Huge Impact on Economic Growth and Productivity. Retrieved from https://www.aei.org/articles/why-goldman-sachs-thinks-generative-ai-could-have-a-huge-impact-on-economic-growth-and-productivity/
23. Lipton, Z. C. (2016). The Mythos of Model Interpretability. Communications of the ACM, 59(10), 36-43.
24. Lee, J. D., & See, K. A. (2004). Trust in Automation: Designing for Appropriate Reliance. Human Factors, 46(1), 50-80.
25. O'Neil, C. (2016). Weapons of Math Destruction: How Big Data Increases Inequality and Threatens Democracy. Crown Publishing Group.
26. Kore, A. (2023). Designing great AI products - Building trust. Retrieved from https://becominghuman.ai/designing-great-ai-products-building-trust-26f8d5c1fcdd
27. Liu, Y., Zhang, X., & Zhang, J. (2019). Data Privacy and Security in AI Systems: A Survey. Information Systems Frontiers, 21(5), 1079-1095.
28. Dignum, V. (2018). Ethics in Artificial Intelligence: Introduction to the Special Issue. AI & Society, 33(2), 167-172.
29. Angwin, J., Larson, J., Mattu S., & Kirchner L. (2016). Machine Bias: There's Software Used Across The Country To Predict Future Criminals And It's Biased Against Blacks. ProPublica.
30. Benneh, G. (2023). Addressing Ethical Concerns in Artificial Intelligence: Tackling Bias, Promoting Transparency and Ensuring Accountability. Retrieved from https://www.researchgate.net/publication/375860770_Addressing_Ethical_Concerns_in_Artificia

l_Intelligence_Tackling_Bias_Promoting_Transparency_and_Ensuring_Accountability#:~:text=Three%20main%20ethical%20imperatives%20for,to%20hold%20organizations%20responsible%20for

31. Butterworth, M. (2018). The ICO and artificial intelligence: The role of fairness in the GDPR framework, Computer Law & Security Review, Vol. 34/2, pp. 257-268.
32. OECD publishing, (2023). Advancing accountability in AI. Governing and managing risks throughout the lifecycle for trustworthy AI. Retrieved from https://www.oecd-ilibrary.org/docserver/2448f04b-en.pdf?expires=1731669844&id=id&accname=guest&checksum=8D620834487AE7E818BC414781D8D6B6
33. De Cristofaro, E. (2020). An Overview of Privacy in Machine Learning. Retrieved from https://arxiv.org/abs/2005.08679

Chapter 4 Innovation and Management in the Age of Digital Transformation

INNOVATIVE AND INFORMATIONAL BUSINESS SOLUTIONS IN THE ERA OF INDUSTRY 4.0

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Absract

Many countries of the world, feeling the crisis of capitalism, observe how in the modern conditions of development, innovative enterprises found themselves in a situation of destruction of the entrepreneurial ecosystem, and therefore lost contact with the university environment, bodies of executive, investors and other stakeholders. The free innovation and information chain are disrupted, more and more processes are becoming manageable and predictable. In order to solve such problems at the theoretical level, it is proposed to find effective innovative and informational solutions. In particular, to investigate the increasing level of freedom under which the results of the development of science and technology cross national borders in the form of scientific works, goods, ideas, qualified specialists, as well as technological, production and marketing know-how. The main areas of activity of leading companies and transnational corporations as the main carriers of technoglobalism are analyzed.

An analysis of global trends in the development of certain advanced technologies was carried out. The critical range is indicated for such new technologies as Applied AI (2030), Autonomous systems (2025), Advanced algorithms (2030), Symbiosis "man-machine" (2035). According to the method of determining the level of technological readiness in the program (project) – TRL – according to the level of the most mature technology from 1 to 9, the following ratings are given: Applied AI – 6; Autonomous systems – 6; Advanced algorithms – 4; Symbiosis "man-machine" – 4. Accordingly, the type of impact is given: for Applied AI, Autonomous systems and Advanced algorithms it is revolutionary, for Symbiosis "man-machine" – high.

Keywords: *innovations, technologies, knowledge, information, robotics, science, business, education.*

Introduction

At a time of powerful militarized influence on the further development of world and national economies, there is an extremely high rate of spread of new ideas and technologies, which are provided by various programs to support the security and defense sectors of countries. An important condition for innovative solutions in modern conditions of development is compliance with the needs of institutions and institutions on security and defense issues of each country, the construction of

analytical solutions within the framework of such initiatives as defense governance, resource management, planning based on capabilities, etc. All over the world, we are observing an active phase of the work of the institutional and economic mechanism of ensuring the innovative development of society in the conditions of deepening technological globalization, wide and comprehensive distribution and penetration of technologies into all spheres of life. This process is accompanied by collaboration, increasing the volume and dynamics of transfers of technologies and innovations in the global economic space.

In the direction of theoretical and practical support for the spread of innovations and information solutions in the era of Industry 4.0, a significant number of works by scientists and practitioners are known. The author is a supporter of both the basic and the latest provisions of the theory of social development, systemology, strategic, production and innovation management. The main methods of research are the description, observation, analysis and generalization of socio-economic realities, as well as the method of conjunctural reviews and forecasts, monitoring of mass media, benchmarking, methods of modern technology Data mining (modeling, forecasting and fuzzy logic), foresight.

Results

After gaining independence, Ukraine actively participated in international scientific and technical cooperation, signing agreements with more than 30 countries in the first decade of sovereignty alone (with the Governments of the Republic of Korea, the State of Israel, the United Kingdom of Great Britain and Northern Ireland, the Republic of Lithuania, the Islamic Republic of Iran, etc.). In addition, by 2020, the state has adapted 17 global SDGs, among which almost half are aimed at introducing innovative technologies and improving the efficiency of natural resource use.

The priority areas of scientific, technological and innovative cooperation between Ukraine and EU member states are:

- modern information and communication technologies, the field of cyber security;
- digital technologies (IoT, VR, AR, ML, AI, BD, AM technologies (3D printers));
- biotechnology, nanotechnology, geoengineering in the fields of health care and pharmacology, agriculture, food and other industries;
- research in the field of agriculture and forestry, precision farming;
- life sciences, medical and biological sciences (biomedicine), genomic research;
- environment and climate research, efficient use of natural resources, renewable energy and energy efficiency;
- rocket and space industry;
- aviation research and aircraft construction;
- nuclear energy;
- materials science, new substances and materials;
- industrial cyber-physical systems;
- modern transport technologies;
- creative industries;
- research in the field of humanities and social sciences (Omelyanenko, V. et al., 2022).

Industry 4.0 signifies a seismic shift marked by intelligent machines, connected devices, and informed, data-driven decisions. It's revolutionizing traditional business models, transforming supply chain management, and redefining stakeholder interactions. This revolution is reshaping industries and blurring the lines between digital, physical, and biological realities (IMD, 2024). Industry 4.0 transformations allow us to work alongside machines in new, highly productive ways (Burrus, 2024). The report on technologies and innovations identifies 11 advanced global technologies:

- the Internet of Things (in this technology, the Internet is used to exchange information not only between people, but also between various "things", that is, machines, devices, sensors, etc. On the one hand, things equipped with sensors can exchange data and process them without human intervention. On the other hand, a person can actively participate in this process, for example, when it comes to a "smart house". A type of IoT is the Industrial Internet of Things (IIoT). It is he who opens a direct path to the creation of fully automated production. It all starts with the fact that the key components of the equipment are provided by various sensors, actuators and controllers; the collected data is processed and sent to the relevant services of the enterprise, which allows the staff to quickly make informed and balanced decisions. But the maximum task is to achieve such a level of automation of the enterprise that machines work without the participation of people in all areas, where possible. In this case, the role of personnel is limited to controlling the operation of machines and responding only to emergency situations); robotics (currently, robotics is still in the initial phase of development. And in order to bring it to a qualitatively new level, it is necessary for robots, at a minimum, to acquire excellent skills in recognizing human speech and gestures, fine motor skills, synthesis and analysis of the external environment and social communication. Accordingly, the development of robotics directly depends on the development of related industries, because this is the only way to expand the performed tasks and improve the quality characteristics of the equipment. Creating robots is a painstaking and high-tech process. It is necessary to clearly build the algorithm of the manipulator, calculate the load processes along several axes and ensure long-term trouble-free operation. All this is possible only when using materials and components of the appropriate quality and those that have given mechanical, chemical and technological properties. What the robot of the future will look like is influenced not only by production and economic factors. Their appearance and functionality will also be determined by the environmental component, the degree of interaction between robots and people, the need for socialization of robotic devices and the development of related industries. Yes, high-speed Internet will increase the level of self-organization and expand the optionality of robotic equipment. And the post-pandemic period and global wars created very important prerequisites for the global automation of online shopping platforms and the creation of robot couriers capable of packaging, delivering and even reheating food).
- According to the international standard ISO 8373: 2012, a robot is a drive mechanism programmed along two or more axes, having a certain degree of autonomy, moving within its working environment and performing tasks assigned to it. This is an automatic device that, thanks to a special built-in program, is able to perform certain mental and physical tasks instead of a person. Modern models can not only understand the surrounding world with the help of sensors, but also independently make decisions and build behavior models. The robot

must meet the following conditions: SENSE: perception of the world with the help of sensors – microphone, cameras, electromagnetic or electromechanical sensors; THINK: understanding the environment and building an appropriate model of behavior to complete the written tasks; ACT: impact on the external environment. Intelligence enhancement, strategy development, social manipulation, computer hacking, technological developments, economic efficiency - a system capable of solving all these tasks can create its own long-term plan and reject options for actions that lead to its defeat. The only question is what will be the motivation of the supermind. More or less any level of intelligence can, in principle, be combined with more or less any ultimate goal. Superintelligent agents, or agents, will – with the widest variety of ultimate goals – pursue similar intermediate goals, since all agents will have the same instrumental reasons for doing so. These goals can be, for example, self-preservation, obtaining resources, strengthening one's cognitive abilities, improving technologies;

- artificial intelligence (AI) (undoubtedly, artificial intelligence is a technology capable of changing the future. It can generate almost anything from images to complex analytics. The artificial intelligence market is expected to reach $407 billion by 2027, growing at a CAGR of 37.3% from 2023 to 2030. In order for artificial intelligence (AI) to be able to perform the assigned tasks, it needs to process huge arrays of data. For example, in order for AI to distinguish wind farm turbines from an ordinary windmill, it must "sift" through millions of images of wind farms. Information processing takes place in data centers that have large computing power and require a huge amount of energy. Therefore, there are many alternative opinions about this technology);
- production of electricity using solar energy (Solar energy is one of the most promising alternative methods of obtaining electrical energy. Firstly, sources of radiation (thermonuclear reactions on the Sun) are inexhaustible. Secondly, solar panels are characterized by durability, strength and safety for the environment);
- unmanned technologies (for example, cargo drones, programmable gloves, control of various vehicles, driverless trains, autonomous loading or unloading, autonomous drilling and blasting, scalable solutions for mines and mining, hydraulic buses, mobile applications as driver assistants, driverless cars, driverless technologies for agro-industrial complex, teleports, etc.);
- big data (Data Driven Decision / BD) (large amounts of information accumulated as a result of the "digitization" of the physical world can be effectively processed only by computers (in the future, perhaps quantum), using cloud computing and artificial intelligence technologies. As a result, a person who controls this or that process, situation, environment should receive processed data that is as convenient as possible for perception, analysis and decision-making);
- nanotechnologies (the use of nanotechnologies is so promising that their research does not stop even for a day. And in the process of designing new ideas and innovations, the best specialists in this field have been involved for a long time. Among the most recent discoveries in the nanosphere, we can name the creation of a tiny device for transmitting a holographic image (which is already predicted to be used in the advertising industry, as well as a supplement in Internet communications), the creation of nanofilm for use in flexible solar

cells and as a conductor of electricity, the creation of nanorobots, able to move in liquid and in the future become a new turn in nanomedicine, the creation of nanorobots capable of independently repairing damage in their electrical circuits);

- new communication protocols (5G) (a new generation of mobile Internet, which should provide much faster data transfer to and from the phone, wider coverage and more stable communication. Better use of the radio range and the possibility of simultaneous access to the mobile Internet for more devices);
- blockchain (the growing popularity of various types of cryptocurrencies, in particular, bitcoins, has led to the emergence of special terms related to cryptographic technologies. One of them – blockchain – is one of the key concepts of the basis of modern cryptographic systems. The main rules that the "ideal" blockchain model must obey, regardless of the area of its application: continuity of the chain, that is, breaks are unacceptable, but branches are possible; instantaneous occurrence of events included in the block; chain succession, that is, each subsequent block, in addition to the set of its actions, contains the result of the "work" of the previous one; irreversibility of actions, that is, changes in the results and composition of actions of any of the blocks are unacceptable; unlimited number of copies of the chain; control of results, i.e. verification of the contents of the blocks of each copy before adding a new block of operations. In addition to its use in cryptographic systems, the technology is gradually beginning to "enter" such areas as banking, cybersecurity, the gaming industry, construction, investments, stock exchanges, online voting and many others. Thus, the Central Bank of India has already begun to use the technology in practice for making money transfers abroad since mid-2022. Specialists from banks such as Innovation Lab, Alfa-Bank and many others are preparing to implement the model in their institutions. Ukraine, the UAE and Sweden are preparing the basis for using the technology for the functioning of their state Land Registries);
- genetic engineering (genetic modification) (nowadays, the theory of circular economy is at the center of socio-economic existence, while at the center of science is collaboration, intersection of different scientific directions with the aim of producing innovations. Likewise, genetic engineering is a branch of science on the border of molecular biology, molecular genetics, and biotechnology, the goal of which is to create organisms) (NIH, 2024);
- 3d printing (additive technologies) – is one of the forms of additive manufacturing technologies, where a three-dimensional object is created by applying successive layers of material (printing, growing) according to the data of a digital model) (Technology and innovation report, 2023).

Frontier technologies readiness index by country in 2023 looked like this:

1. United States of America
2. Sweden
3. Singapore
4. Switzerland, Liechtenstein
5. Netherlands
6. South Korea
7. Germany

8. Finland
9. China, Hong Kong
10. Belgium.

According to the Framework Program of the European Union for research and technological development "Europe-2030", the European Union in 2030 will be characterized by the financing of projects with a high social return" and the creation of open ecosystems for research, innovation and education.

At the epicenter of today's knowledge economy is the effectiveness of investing in BDAA (Big Data Architecture and Applications). BD technologies are closely related to AI technologies, which are the main driving force behind modern business and enable machines to perform tasks that require human intelligence.

Table 1. Global trends in the development of some advanced technologies

New technologies / range	**Influence**	**TRL (n = 1…9; 9 is the most mature technology)**
Applied AI (2030)	Revolutionary	6
Autonomous systems (2025)	Revolutionary	6
Advanced algorithms (2030)	Revolutionary	4
Symbiosis "man-machine" (2035)	High	4

Source: systematized by the author according to (Trends in Science and Technology, 2020)

However, in Ukraine and partner countries, a sharp slowdown of the economy is observed from 2022. At the same time, unlike the beginning of a full-scale invasion of the enemy, business and the public are already adapting to new conditions by means of relocation and partner support. Chaotic development begins to take a specific measurable form and outlines the main factors of growth:

- information and data as an asset;
- automation and digitization;
- level of business security;
- innovativeness of business processes.

In the current conditions, when at the same time some industries are being destroyed and the digital sector is growing rapidly, the issues of innovative modernization are of significant importance, and technoglobalism is taking on new forms.

Currently, Ukraine is solving the extremely difficult task of ensuring competitiveness in tough pragmatic circumstances, primarily relying on the outcome of the Russian-Ukrainian war – victory. This once again confirms that in the conditions of technoglobalism, the innovative development of socio-economic systems is of primary importance. The spread and interaction of new ideas and technologies are currently gaining acceptance in social systems very quickly.

Many countries of the world, feeling the crisis of capitalism, observe how in the modern conditions of development, innovative enterprises found themselves in a situation of destruction of the entrepreneurial ecosystem, and therefore lost contact with the university environment, bodies of executive, investors and other stakeholders. The free innovation and information chain is disrupted, more and more processes are becoming manageable and predictable. In the EU, the process of

innovative modernization is clearly regulated in many documents, in particular, "Green" and "White" books. The former initiate a public discussion, the latter – specific proposals. Among the first ones that touch on issues of technology, information, verification and innovation are: "The European Research Area: New Perspectives", "European Space Policy", "The future of the European migration network", "Public Access to Documents held by institutions of the European Community", "Agricultural product quality: product standards, farming requirements and quality schemes", "Copyright in the Knowledge Economy", "TEN-T: a policy review: towards a better integrated trans-European transport network at the service of the common transport policy", "The Community patent and the patent system in Europe", "The online distribution of audiovisual works in the European Union: opportunities and challenges towards a digital single market", to the second – "Space: a new European frontier for an expanding Union An action plan for implementing the European Space policy", "Education and training", etc.

Innovative modernization is closely related to digital transformation of business - revision of corporate, business, functional strategies and development models of business organizations. It is based on the robotics of production and business processes, artificial intelligence, multi-channel collection and analysis of big data, etc. And that is why there is often a change of concepts: instead of innovation projects, enterprises are engaged in digital transformation.

An example of successful modern innovations in science is the change in the nature of scientific discoveries, which consists in the synergy of various sciences, a cross-functional interdisciplinary approach. Innovations in this case arise "at the intersection" of the application of knowledge in the field of informatics, VRR, LM, TQM, TVM, ecohomology, controlling, regionalism, change management, benchmarking. Modern innovations in education are represented by open education, innovative methods of distance education and training, which can be more effective than traditional, e-education, Edtech, STEM. In addition, innovation is applied in philanthropy in the form of combining ideas from the field of finance and philosophy and forming an innovative philanthropic strategy for philanthropy; innovations in tourism (virtual reality, augmented reality, gastronomic tourism, e-tourism), innovations in biology, medicine, in the field of health care, innovations in military technologies (C4ISR, space quantum sensors, artificial intelligence, autonomous control, hypersonic systems) (Prokopenko, O. & Välk, K. et al., 2024).

Conceptual provisions regarding the diffusion of innovations were introduced in the late 19th and early 20th centuries. scientists Zh.-H. Tard (described the process of borrowing innovations as imitation, 1890), J. Schumpeter (introduced the concept of "innovation", described the complexity of diffusion, 1911-1930), E. Rogers (spread the term "diffusion of innovations", 1962) and T. Hegerstrand (authors of the innovation diffusion theory), B. Ryan, N. Gross, I. Perlaky, V. Hartman, B. Twiss, E. Mansfield, and others. Today, many scientists of the world investigate the theoretical and practical issues of the diffusion of innovations, prove their great significance for society and every person, see them as the most valuable resource. However, in the created conditions of informational chaos, post-Fordism, mistrust of state institutions, severe economic crisis due to the war, in short, total uncertainty, the issue of the spread of innovations needs further study. A significant contribution to the study of the problem of supporting the diffusion of innovations in entrepreneurship was made by modern Ukrainian scientists N. Chuhrai, N. Krasnokutska, N. Matviychuk-Soskina, H. Shamota, O. Prokopenko, V. Liashenko and others.

The natural nature of innovations, on the one hand, and their coherence with absolutely all spheres of activity, make innovations a unique phenomenon (Table 2).

Analyzing the business spheres of the TOP companies and multinational corporations in the world, we see their concentration in the field of high-tech services. Among them:

- ServiceNow (IT Software & Services, USA) – engages in the provision of enterprise cloud computing solutions. It offers customer and facilities service management, orchestration core, service mapping, cloud and portfolio management, edge encryption, performance analytics, service portal designer, visual task boards and configuration management database. The firm offers its solutions for the industries under the categories of Healthcare, Education, Financial services (Forbes, 2024);
- Workday (IT Software & Services, USA) – engages in the development of enterprise cloud applications for finance and human resources. It delivers financial management, human capital management and analytics applications designed for companies, educational institutions and government agencies (Forbes, 2024);
- Salesforce.com (IT Software & Services, USA);
- Tesla (Automotive (Automotive and Suppliers), USA) – a top corporation that can be called innovative in matters of creating shared value. The Energy Generation and Storage segment includes the design, manufacture, installation, sale, and lease of stationary energy storage products and solar energy systems, and sale of electricity generated by its solar energy systems to customers. It develops energy storage products for use in homes, commercial facilities and utility sites (The World's Most Innovative Companies, 2024);
- Amazon.com (IT Software & Services, USA);
- Netflix (Media & Advertising, USA);
- Incyte Corp. (Drugs & Biotechnology, USA) is a biopharmaceutical company, which engages in the discovery, development and commercialization of proprietary therapeutics. Its portfolio includes compounds in various stages, ranging from preclinical to late-stage development, and commercialized products such as JAKAFI (ruxolitinib), and ICLUSIG (ponatinib) (The World's Most Innovative Companies, 2024);
- Facebook (IT Software & Services, USA) – an exemplary representative of the generation of innovative and informational solutions, because the platform itself is the largest innovative and social hub in the world.

Table 2. Examples of application of innovations in various spheres of activity

Field of activity	Examples	Applied knowledge of other fields of activity
Innovations in science	changing the nature of scientific discoveries, which consists in the synergy of various sciences, a cross-functional interdisciplinary approach*	Informatics, VRR, LM, TQM, TVM, SIM, ecohomology, controlling, regionalism, change management, benchmarking
Innovations in education	open education; innovative methods of distance education and training, which can be more effective than traditional ones; e-education; Edtech; STEM	Informatics, pedagogy, androgogy, psychology, marketing, innovative technologies
Innovations in banking	credit cards; e-commerce, Internet banking; FinTech	Informatics, marketing, e-commerce
Innovations in charity	combining ideas from the field of finance and philosophy and forming an innovative philanthropic charity strategy	Informatics, psychology, marketing, sociology
Innovations in tourism	virtual reality, augmented reality, gastronomic tourism; e-tourism	Informatics, tourism, marketing
Innovations in the restaurant business	competitive technologies that have significantly improved the structure and/or quality of products and services, such as chains of fast food establishments	Informatics, psychology, marketing
Innovations in the food industry	application of genetic modification (CRISPR systems)	Informatics, marketing, molecular biology, aristology, biochemistry
Innovations in biology, medicine	cloning, organ transplantation	Genetic engineering, anatomy, biology, computer science
Innovations in the field of health care	antibiotics; e-health; products of Pfizer, Roche, Johnson&Johnson, GE, Biogen, Amgen (biotechnologies)	Immunology, virology, neurophysiology, anatomy, anthropobiology, biometrics, bionics, bacteriology, geoengineering, pharmacology, microbiology
Innovations in the social sphere	creation of social networks, search engines	Informatics, axiology, ethics, sociology, marketing
Innovations in trade	Internet marketing, e-commerce, RFID, NFC, SoLoMo	Informatics, social and behavioral sciences
Eco-innovations	application of RES, nanotechnology, biotechnology, development of ADE, (Tesla Motors electric cars), green branding, eco-labeling	Informatics, biocenology, regional studies, marketing, energy management, ecology
Innovations in military technology	C4ISR**, space quantum sensors, artificial intelligence, autonomous control, hypersonic systems	(Bio)informatics, avionics, aerostatics, medicine, kinematics, toxicology, cognitology, STEM

** "New discoveries that will forever change the world will arise from the intersection of disciplines, and not from separate isolated fields of knowledge" (Johansson, 2006);*

*** C4ISR: C4 – command, control, communications, computers; ISR – Intelligence, Surveillance and Reconnaissance. Advanced C4ISR capabilities provide an advantage through situational awareness, knowledge of the adversary and the environment, and reduced time between sensing and response (Trends in Science and Technology, 2020)*

It is quite obvious that the business areas of the TOP-10 startups in the world are similar: Open AI is a leading AI research and deployment company committed to harnessing the potential of artificial intelligence for the betterment of humanity with a focus on safety and prioritizing human interests, Cutt.ly, Revolut, pCloud, Appy Pie, etc. (Startup Ranking, 2024). The largest companies by market capitalization are Saudi Arabian Oil, Apple, Microsoft, Amazon Inc., Alphabet Inc./ (Google), Facebook Inc-A, Tencent, Alibaba Group, Berkshire hath-A, Visa Inc-class A. And the largest public companies in the world – ICBC, China Construction Bank, JPMorgan Chase, Berkshire Hathaway, Agricultural Bank of China, Saudi Arabian Oil Company, Ping An Insurance Group, Bank of America, Apple.

According to the ranking of world economies Digital Evolution Scorecard 2020, which is compiled on the basis of 160 indicators, it tracks four main factors: supply, demand, institutions and innovations (the latter permeate the previous three) (Chakravorti, B., Shankar Chaturvedi, R. & Bhalla, A., 2019):

I. Proposal: how developed is the digital environment and physical infrastructure necessary for building a digital ecosystem? (availability of broadband Internet, quality of roads for delivery of goods from online stores, etc.).

II. Demand: Are consumers willing and able to participate in the digital economy? Do they have the necessary tools and skills to connect to it?

III. Institutions: Do country laws (and government actions) facilitate or hinder the development of digital technologies? Does the government invest in digitalization? Do the adopted measures of state regulation encourage or, on the contrary, inhibit the use and storage of data?

IV. Innovation: how developed are the main components of innovation ecosystems (access to talent and capital, processes, new digitally scalable products and services).

In the above-mentioned study, the economies of the countries were divided into four groups: leaders, promising ones, those that slow down development and problematic ones.

The first have the highest initial level of digitalization and a powerful pace of development of this sphere, adaptability and institutional support for innovations. The leading countries are Singapore (with a significant margin), South Korea and Hong Kong, as well as the USA, Germany, Estonia, Israel, the Czech Republic, Lithuania, the UAE, Taiwan, Malaysia and Qatar. These countries are characterized by support for the introduction of digital consumer tools (Internet trade, digital payments, entertainment, etc.); attraction, training and retention of IT personnel; growing digital startups; provision of fast and publicly available access to terrestrial (optical fiber) and mobile Internet; specialization in the export of digital goods, services or media; coordinated innovation process: universities, business and authorities responsible for digital development.

According to the rating (Chakravorti, B., et al., 2019), promising economies of countries are characterized by limitations of digital infrastructure and rapid digitization. This zone includes China (with a significant margin and the highest rate of digital evolution), Indonesia and India, as well as Kenya, Vietnam, Bangladesh, Rwanda, Algeria, Argentina, Poland, Saudi Arabia, Bulgaria, Georgia,

Azerbaijan, Serbia and Ukraine. These countries are characterized by setting and achieving the following goals: improving mobile Internet access, its availability and quality for a deeper spread of innovations; strengthening of the institutional environment and development of digital legislation; encouraging investment in digital enterprises, financing digital R&D, training IT personnel and using applications to create jobs; measures to reduce inequalities in access to digital tools along gender, class, ethnic and geographic lines.

Slow development corresponds to an area with mature digital systems, but a low rate of further development. Includes mainly EU countries: Denmark, the Netherlands, Sweden, Switzerland, Finland, Norway, Great Britain, France, Austria, Belgium, Spain, Portugal, Slovenia, New Zealand, as well as Japan and Canada. These countries are characterized by protection against "digital plateaus": further investment in stable institutional pillars, regulatory environment and capital markets to support further innovation; using policy tools and regulation to ensure equal access to digital opportunities and protect all consumers from privacy breaches, cyber attacks and other threats (preserving data availability for new digital applications); attracting, training and retaining professionals with digital skills – most often with the help of immigration policy reforms; identifying new technological niches and creating ecosystems that promote innovation in these areas.

Troubled economies of countries are characterized by both problems in the existing digital ecosystem and a low growth rate. This zone includes the countries of Africa, Asia, Latin America and Southern Europe. Among them are Slovakia, Hungary, Romania, Croatia, Pakistan, Egypt, Tunisia, Mexico, Brazil, South Africa, Turkey, Greece, Nigeria, Ethiopia. The economies of these countries should have the following priorities: long-term investments in solving basic infrastructure problems; creating an institutional environment that supports the safe and widespread distribution of digital products and services among consumers, especially if these products contribute to productivity and the creation of new jobs; supporting initiatives to develop digital access for historically disadvantaged population groups (especially through state cooperation with private business); supporting applications that solve pressing problems and thus can become catalysts for the spread of digital tools (for example, digital payment platforms).

Regarding the current situation in Ukraine, currently the vast majority of innovative enterprises are collective and state-owned, in contrast to the majority of foreign innovative enterprises. They are concentrated in various spheres of activity: finance (Privatbank), machine building (SE "Pivdenny Machine-Building Plant named after O.M. Makarov", CB "Southern" named after M.K. Yangel), freight transportation (LLC "Nova Poshta"), pharmaceuticals ("Darnytsia"), power engineering ("Turboatom"), software (Grammarly), e-commerce ("Rosetka"), agricultural industry ("Kernel", "Svarog West Group"), military industry ("Ukroboronprom"), retail ("Silpo"), the Internet of Things (Petcube), etc. Privately owned innovative enterprises are mostly concentrated in the pharmaceutical sector ("Pharmak"), agro-industrial complex (MHP "Myronivskyi Hliboprodukt", "Nibulon", "AgriLab"), alternative energy ("Eko-Optima"), wind energy ("Wind Power"), PEK ("Oil and Gas Production"), etc. (Nikishyna, O. & Bondarenko, S. et al., 2024).

Innovative development requires the necessary research and production potential in the country. This requirement stems from the high scientific intensity of all technological components that create an innovative ecosystem and ensure its effective functioning. The largest number of technologies (investment projects) in Ukraine was declared in the fields of instrument building, new materials and

substances, agriculture, mechanical engineering, and medicine; none – in genomics, programming theory, phytocenology, sensorics, medical botany, zoology, molecular biology and genetics. We will give a description of the new Strategy for recovery, sustainable development and digital transformation of small and medium-sized enterprises of Ukraine, which in the conditions of war is a challenge, an action plan and hope for a quick recovery of all economic processes in the country, in particular for innovative development. This strategy was developed for the period until 2027 by the Ministry of Economy of Ukraine, the Ministry of Digital Transformation of Ukraine and the state institution "Office for Entrepreneurship and Export Development" with the support of: Kyiv School of Economics (KSE); Ministry of International Development of Great Britain; Good Governance Fund – a technical assistance project financed by the UK Government; an EU initiative that helps entrepreneurs in five countries of the Eastern Partnership – Armenia, Azerbaijan, Georgia, Moldova and Ukraine; international provider of research, consulting, program management and communication services ECORYS; Office of Effective Regulation BRDO – a leading independent analytical center in the field of economic regulation with a focus on implementation; the German Society for International Cooperation GIZ.

Key challenges for SMEs are defined as:

- lack of working capital;
- destruction of logistics chains;
- loss (impossibility) of finding highly specialized specialists;
- cost growth (utility payments, raw materials);
- impossibility of forecasting/strategizing due to uncertainty;
- drop in demand (loss of sales markets) (Strategy for recovery, sustainable development and digital transformation of small and medium-sized enterprises, 2024).

All of the above-mentioned indicators are defined as unsatisfactory, their value varies greatly from normative ones, reaching critical ones. Thus, in the first year of the war, the lack of working capital in SMEs amounted to 44%, which means complete bleeding of business. However, in the second year of the war, the situation improved somewhat and this indicator averaged 29%. Wartime business support programs (the State Business Relocation Program, affordable factoring, affordable credit, affordable financial leasing, and some promotion of transparency in public procurement) did the trick. With international support, the business survived. But the biggest shock for him was the drop in demand/loss of sales markets (77% and 57% in the first and second years of the war, respectively. As a result of the full-scale invasion, there was a significant destruction of logistics chains (52 percent in the first and 33 percent in in the second year of the war) the growth of the indicator is due to the preservation of export supplies as much as possible, the change of export and import logistics channels significant restructuring of logistics is taking place. The most painful issue was and is the loss or inability to find highly specialized specialists on the labor market. It should be noted that in the first year of the war this indicator was 27 percentage points, but in the second year it significantly increased to 44 percentage points, which indicates the weakness of government programs. The growth of fixed costs amounted to 70% and 53%, respectively, in the first and second years of the war. In addition, experts noted the indicator of the impossibility of forecasting (strategizing) due to uncertainty (68 and 55%), since it is completely undesirable and difficult to restore business in chaotic conditions. 57% of SMEs were fully operational in 2022, and 85% in 2023. According to estimates, 6% of SMEs temporarily

stopped their activities in the first year of the war, and 1% in the second. It is important to maintain such positive dynamics, especially in the difficult conditions of changes: the increase of the military tax from 1.5% to 5% and a number of other taxes and fees. The 2024-2027 strategies (restoration and facilitation of entrepreneurship, innovative, digital and green transformation, human capital and entrepreneurship culture, competitiveness and increase in exports), according to experts, are capable of giving high results. In particular, in 2027, the "Freedom of doing business" indicator in the Index of Economic Freedom should increase to 75 (now it is 61), the "Science intensity of gross domestic product" will increase to 0.7% (from 0.3% in 2022, 0.5% in 2019 in Ukraine and 1.8% in the USA). According to experts, the unemployment rate should decrease from 18% to 11%. It is extremely important that this indicator does not lose quality and is reliable. Finally, the number of exporters among SMEs should increase from 27,300 in 2021 to 35,000 and more in 2027. So, we state a very optimistic scenario of recovery, sustainable development and digital transformation of Ukrainian SMEs.

Describing all the participants of the new innovation era, it is worth paying attention to smart machines. As always, innovations become a breath of fresh air precisely in times of force majeure, uncertainty, and wars. Ukraine and Israel are in need of innovation most of all now, being in the conditions of war. A common thesis is that machines are changing war. This is done through the improvement of weapons and methods of warfare. Unmanned systems, target recognition systems for air and ground platforms, spy software, etc. are now greatly improved. Modern military equipment continues to develop, but now its effectiveness is determined not so much by armor and firepower as by digital technology. For example, the purpose of tanks today is not limited to overcoming trenches, they are autonomous combat machines thanks to processors, artificial intelligence, compact computers and cloud services. In addition to smart technologies, smart organization, smart company, and smart production are now widespread. "Tag cloud" allows you to reveal an interesting feature in the definition of the categories mentioned above. All of them are socially oriented, multifunctional, highly managed, created by highly motivated people who believe in the purpose of Smart Machines and their service to humanity. The implementation of "smart" technologies in our new realities is only gaining relevance. They are able to help take care of the safety of the population and ensure effective interaction and provision of services remotely. These services include: centralized operational notification of an air alarm; applications for sharing information, such as ePPO, with the help of which the population helps the Defense Forces to repel the enemy; solutions in the field of electricity supply and energy saving to avoid blackouts in the conditions of shelling of the energy infrastructure; decisions in the field of documenting war crimes such as EyeWitness; financial technologies – electronic payment systems and digital assets; the use of drones, robots and self-propelled machines in agriculture, especially with regard to mining; systems for remote monitoring of equipment, which allow you to manage processes without suspending them even when it is not possible to be physically present at the site; electronic tools that make it possible to register applications for housing, such as special online forms on the websites of city councils or the nationwide resource IGOV; e-services or e-tools related to social services; chatbot tools for submitting complaints, appeals or petitions; services for electronic registration in schools and preschool education institutions.

Conclusions

In order to prevent the problems of bias in making innovative decisions, in today's world of technology and unlimited information, the natural essence of innovation, their coherence with absolutely all spheres of activity, which make innovation a unique phenomenon, should be investigated. In the era of Industry 4.0, it is relevant to study the regularities of development processes, the formation of innovations, change management mechanisms, overcoming resistance to innovations, human adaptation to them, the use and spread of innovative flows, ensuring security guarantees.

The tag cloud allows us to identify a common feature in the definition of "smart organization", "smart company", "smart production", because they are all socially oriented, multifunctional, highly managed, created by highly motivated people who believe in the purpose of Smart Machines and their service to humanity. Analysis of global trends in the development of certain advanced technologies will establish a critical range for such new technologies as Applied AI (2030), Autonomous systems (2025), Advanced algorithms (2030), and human-machine symbiosis (2035). According to the method of determining the level of technological readiness in the TRL program, according to the level of the most mature technology, from 1 to 9, scores are given: Applied AI - 6; Autonomous systems – 6; Advanced algorithms – 4; Human-machine symbiosis – 4. Accordingly, the impact type is given: for Applied AI, Autonomous Systems and Advanced Algorithms – revolutionary, for Human-machine Symbiosis – high.

References

1. Omelyanenko, V., Pidorycheva, I., Voronenko, V., Andrusiak, N., Omelianenko, O., Fyliuk, H., Matkovskyi, P. & Kosmidailo, I. (2022). Information & Analytical Support of Innovation Processes Management Efficience Estimations at the Regional Level. *International Journal of Computer Science and Network Security*, 22, 6, 400-407. http://paper.ijcsns.org/07_book/202206/20220650.pdf
2. What Is Industry 4.0 and the Fourth Industrial Revolution? (2024). https://www.imd.org/blog/digital-transformation/industry-4-0/
3. What is "Industry 4.0" and what does it mean for front-line workers? World Economic Forum Annual Meeting Jan 8, 2024. https://www.weforum.org/agenda/2024/01/industry-4-fourth-industrial-revolution-workers/
4. Daniel Burrus (2024). AI Strategy Report: Cutting-Edge AI Tool Recommendations to Boost Your Productivity and Efficiency. Burrus Research, Inc. https://www.publishersweekly.com/pw/authorpage/daniel-burrus.html
5. Daniel Burrus (2017). The Anticipatory Organization: Turn Disruption and Change into Opportunity and Advantage. Publisher : Greenleaf Book Group Press, 221.
6. Genetic Engineering National Human Genome Research Institute https://www.genome.gov/genetics-glossary/Genetic-Engineering
7. Technology and innovation report 2023. https://unctad.org/tir2023
8. Trends in Science and Technology 2020-2040. What the NATO study shows. Information agency "Oboronno-promyslovyi kurier" 12.10.2020. http://opk.com.ua/

9. Frans Johansson (2006). The Medici Effect: What Elephants and Epidemics Can Teach Us About Innovation. Harvard Business School Press, 207. https://www.gtnoise.net/downloads/MediciEffect.pdf
10. The World's Most Innovative Companies (2024). https://www.forbes.com/innovative-companies/#7ea2b4e81d65
11. Startup Ranking (2024). https://www.startupranking.com/
12. Bhaskar Chakravorti, Ravi Shankar Chaturvedi, and Ajay Bhalla in HBR "Which Countries Are Leading the Data Economy?". https://sites.tufts.edu/ibgc/bhaskar-chakravorti-ravi-shankar-chaturvedi-and-ajay-bhalla-in-hbr-which-countries-are-leading-the-data-economy/
13. Nikishyna, O., Bondarenko, S., Zybareva, O., Verbivska, L., Zerkina, O. and Chebotarova, N. (2024). A Circular Ecosystem for the Implementation of Sustainable Development Goals Based on Extended Producer Responsibility. *Multidisciplinary Science Journal*, 7 (3). https://malque.pub/ojs/index.php/msj/article/view/2640/2576
14. Strategy for recovery, sustainable development and digital transformation of small and medium-sized enterprises. https://me.gov.ua
15. Todd Earls Industry 4.0 and the drive for long-term growth (2021). https://www.eaton.com/ua/uk-ua/company/digital-innovation/industry-4-0/industry-4-0-and-the-drive-for-long-term-growth.html 30/03/2021
16. Smart Machines and Systems at the Service of Mankind (2024): Abstracts of the 12th Annual Entrepreneurship and Innovation Conference / Gen. edit. Olha Prokopenko, Kristjan Välk, Anne Neroda, Tallinn: Teadmus OÜ, 44
17. Hyseni, V. (2023). Artificial Intelligence, Ethics, and Social Responsibility. *Professional Evaluation and Certification Board*. https://pecb.com/article/artificial-intelligence-ethics-and-social-responsibility
18. Zoltan J. Acs, Abraham K. Song, László Szerb, David B. Audretsch, and Éva Komlósi (2021). The evolution of the global digital platform economy: 1971–2021. *Small Business Economics*, 57, 1629–1659. https://ideas.repec.org/a/kap/sbusec/v57y2021i4d10.1007_s11187-021-00561-x.html
19. Horiashchenko, Y., Taranenko, I., Yaremenko, S., Shevchenko, V., Mishustina, T., & Klimova, I. (2021). Integrated System of Enterprises' Innovative Development Management Under the Conditions of PostFordism. *Postmodern Openings*, 12(3Sup1), 45-60. https://doi.org/10.18662/po/12.3Sup1/350
20. https://ir.duan.edu.ua/handle/123456789/4340/
21. World Bank open data. The World Bank Group, 2024. https://ata.worldbank.org/
22. The UBI Global World Rankings of Business Incubators and Accelerators (2023). https://ubi-global.com/rankings/

INNOVATION MANAGEMENT IN THE DIGITAL AGE: INTEGRATING ARTIFICIAL INTELLIGENCE TO OPTIMIZE BUSINESS PROCESSES

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Abstract

The article examines the importance of innovation and innovative activity for business development and ensuring economic growth. It is emphasized that innovative development in modern business conditions is the foundation for the formation of sustainable competitive advantages of an individual business entity, industry, and the national economy. Therefore, an extremely important task is

optimizing approaches to managing innovative activities based on flexibility, inclusiveness, and adaptability.

Key theoretical and methodological approaches to managing innovative activities are studied, and the main trends in the development of innovative management are also investigated. It is established that further digitalization creates new opportunities for developing business processes, including through the active implementation of artificial intelligence technologies.

A thorough statistical analysis of the global artificial intelligence market is carried out, and an analytical assessment of the state and prospects for developing artificial intelligence technologies in Ukraine is also carried out.

Keywords: *innovation, innovative development, innovative management, artificial intelligence, public-private partnership.*

Description of the article's primary material

The critical factor for successful economic development today is a system of innovative processes, knowledge, and new technologies. Innovations have become critically important for ensuring a sufficient level of competitiveness of enterprises in the national and foreign markets.

Innovations can be technological, involving updating technologies, equipment, and methods of manufacturing new or modernized products. Nontechnological innovations are also associated with changing, updating, and improving approaches to organizing management processes, marketing and sales activities, etc (Fig. 1).

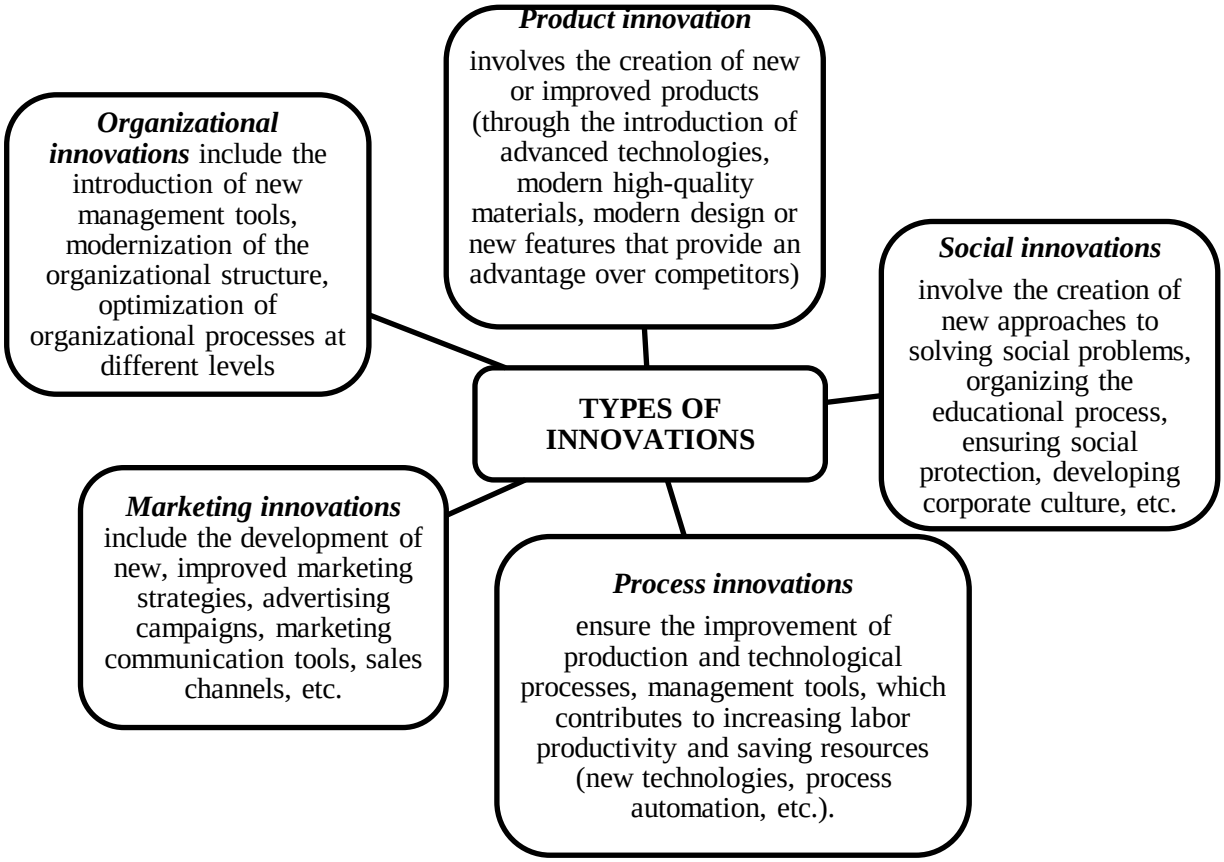


Fig. 1. Types of innovations
Source: summarized by the author based on (Minkovska A.V. & Molchanov A.S., 2023)

Innovations create opportunities for a company to increase market share, enter new market segments, or even open new markets by releasing new products to meet new consumer needs.
Production of new or modernized goods, increased productivity, reduced costs, reduced production cycle time, and other effects of the introduction of innovations ensure the acquisition of new competitive advantages and an increase in the level of competitiveness of enterprises.
Innovations contribute to solving global problems, such as climate change, increased environmental pollution, and irrational use of natural resources. Global challenges determine the development of scientific research and the implementation of innovations in energy efficiency, lean production, waste reuse, etc.
Innovations contribute to successfully scaling a business, creating opportunities for product portfolio diversification, and increasing activities' sustainability and efficiency (Minkovska A.V. & Molchanov A.S., 2023).

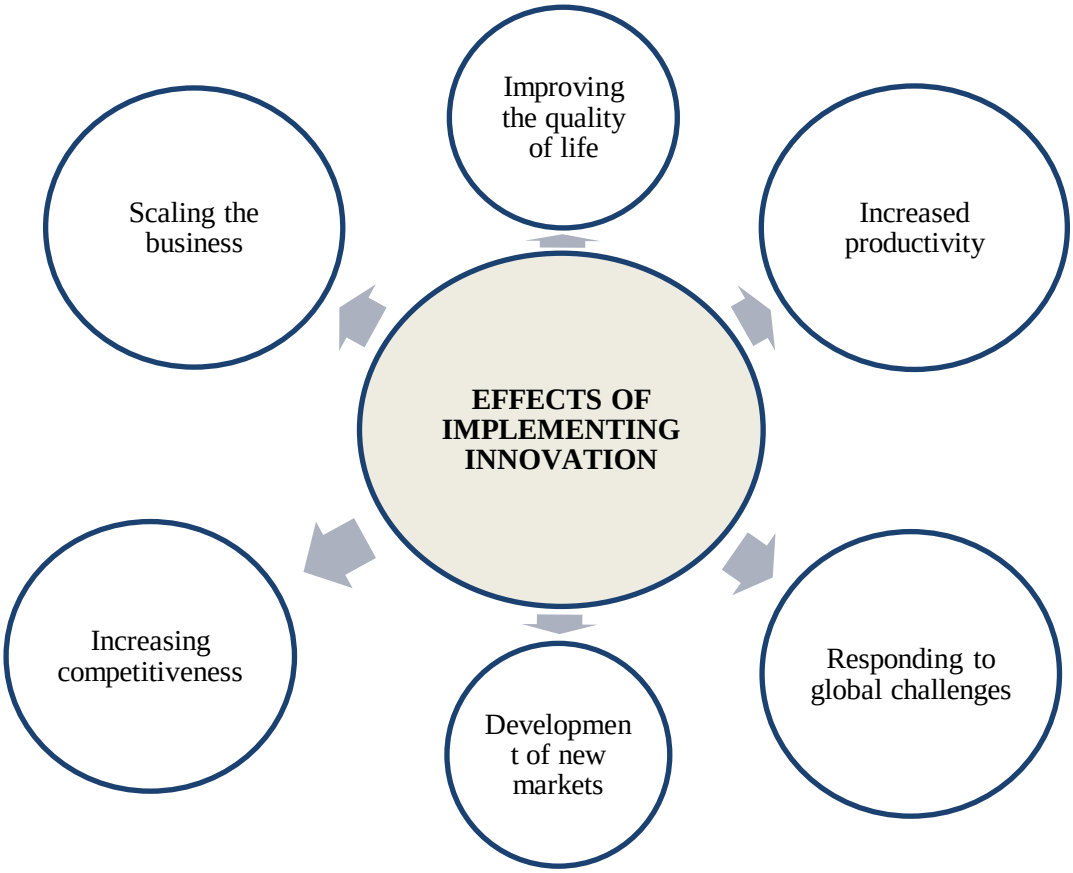


Fig. 2. Key effects of innovation. *Source: authors development*

Thus, the innovative development of the enterprise ensures its stability in a dynamic external environment, creates additional competitive advantages, and is a prerequisite for successful economic growth. Innovative development involves the constant search and implementation of new progressive ideas; the success of these processes is determined by the presence of an effective system of innovation management that is open to change.

Innovation management covers all stages of the innovation management process, starting from the generation of an idea and ending with its implementation in the business entity's activities. Thus, innovation management performs the following essential tasks: search for ideas, organization of research and development (R&D), management of risks associated with the innovation process, and bringing innovative products to the market.

Existing theoretical approaches to interpreting critical principles and features of the organization of innovation management can be conditionally combined into four fundamental concepts: factor approach, functional, systemic, and situational (Fig. 3).

The mechanism of effective innovation management at the enterprise should include several elements.

1. Innovation development strategy – a general direction of innovation development, which involves setting long-term clear and mutually agreed goals that correspond to the enterprise's overall corporate strategy and mission.

2. Organizational structure – a system that defines the hierarchy of departments and teams that participate in determining the goals of innovation development, are engaged in research and development work, and the implementation of innovative solutions in the activities of an economic entity.

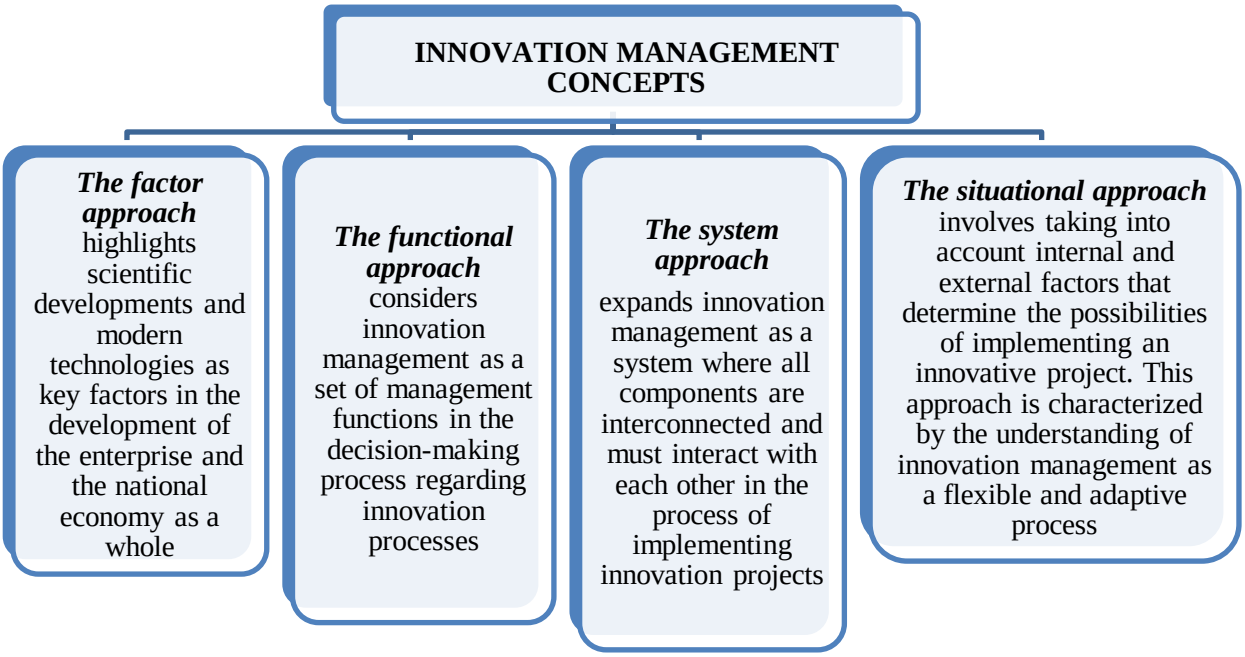


Fig. 3. Key concepts of innovation management. *Source: authors development*

3. Management toolkit – a set of methods and tools for organizing and managing innovation processes at all stages – from idea generation to commercialization.

4. Innovation culture – an essential aspect for activating innovation activity and ensuring the effectiveness of innovation process management at the enterprise. This element includes stimulating creativity, ensuring productive and coordinated teamwork, and supporting open innovation by involving external participants in the innovation process.

5. Knowledge management – systematization of accumulated knowledge and experience in implementing innovations – a prerequisite for forming and using collective intelligence to develop

innovation activity.
6. Innovation financing – accumulation of internal resources and search for additional funding sources for successfully implementing innovation processes at the enterprise.
Management activities define innovation management functions within the "idea generation – research and development – design – implementation of an innovation project." Accordingly, the main tasks of innovation management are as follows.
1) Analyzing the external environment and forecasting the market situation to determine the need and feasibility of implementing a specific innovative idea.
2) Formation of the direction of strategic development of the enterprise's innovation activity, considering the general corporate strategy and the results of forecasting the market situation.
3) Formation of a strategy for financial support of the enterprise's innovation activity – the general need for investment resources to implement the formed innovation strategy is determined, and the possibilities of attracting own and borrowed funds are assessed, considering the principles of financial stability and solvency.
4) Form an innovation portfolio, including projects developed directly at the enterprise and existing projects. The selection of projects considers compliance with the innovation strategy of the business entity, as well as the criteria of profitability, liquidity, and risk acceptability.
5) Current planning and operational management of the implementation of selected innovation projects.
6) Monitoring the implementation process of selected innovation projects. To perform this function, a system of indicators is developed, which diagnoses the compliance of the project implementation process with the established plans and determines the reasons for deviations from the planned deadlines and the effectiveness of project implementation (Shovkun-Zablotska L.V., 2024).
Thus, the critical stages of innovation management include market analysis, nature and strength of influence of external factors; generation of new ideas, their evaluation, and determination of the most successful ones; analysis of internal opportunities for the implementation of selected innovative ideas; scientific research and development of product prototypes; adjustment of production and organizational processes for the implementation of innovations; risk assessment and development of measures to minimize their impact; commercialization and diffusion of innovations.
Innovation management of an enterprise should be based on the following principles:
1) the principle of systematicity – involves considering all elements of the innovation process through their interconnection and interdependence with each other;
2) the principle of flexibility consists in the ability of the innovation management system to adapt to changes in the external environment quickly;
3) the principle of unity of goals – involves ensuring compliance of innovation management goals with general corporate objectives and the mission of the enterprise;
4) the principle of efficiency consists of determining the correspondence of innovative projects' results to their planned values based on a system of indicators, focusing on obtaining maximum profit (Shovkun-Zablotska L.V., 2024).
The dynamism of social and economic processes necessitates the constant development of approaches to innovation management, considering new challenges of the external environment. The key new trends in the development of innovation management are implementing strategies based on openness,

deepening partnership and cooperation, digitalization, inclusion, and social responsibility (fig. 4).
The open innovation model, popularized by Henry Chesbrough, describes a company reaching out to source ideas, technologies, and intellectual property from external sources, fostering collaborative creativity, and developing new products and services. The increasing globalization, diversity, and inclusiveness of the workforce underscore the critical role that collective intelligence and effective collaboration play in driving innovation today.
Effective partnerships and collaborations unlock new sources of creativity and innovation that were previously unavailable. For example, Pfizer's collaboration with BioNTech in 2020 led to the development of one of the first vaccines for COVID-19. The partnership leveraged Pfizer's extensive global distribution expertise and BioNTech's cutting-edge technology. Studies show that companies that engage in cross-industry alliances can increase the number of innovations they introduce by 20%. Such collaborations facilitate the combination of diverse ideas and skills, ultimately leading to innovative solutions unattainable in closed systems. However, effective cross-sector innovation partnerships require strategic planning and a willingness to adapt to change (Vorecol, 2024).

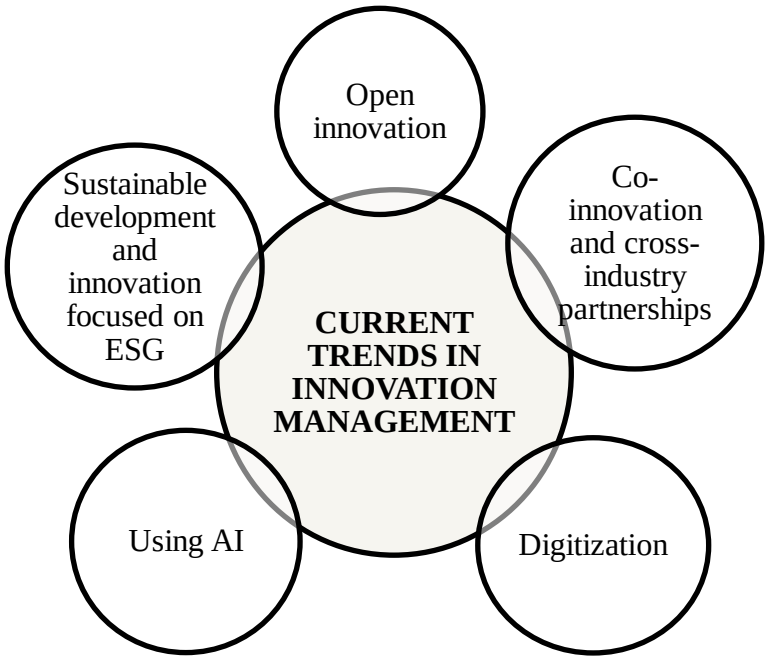


Fig. 4. Modern trends in the development of innovation management.
Source: authors development

LEGO has successfully harnessed the collective intelligence of its open innovation philosophy. With the launch of LEGO Ideas, the company invited fans to submit their own LEGO designs, which the community voted on. This strategy exemplifies how companies can turn their audience into partners, increasing brand loyalty and creating innovative products.
Sustainability has become a must-have in today's business environment, so integrating sustainability into innovation strategies is a crucial trend.
By following its sustainability mission, Interface has reduced its carbon footprint by 96% and saved

over $400 million through innovative energy efficiency and waste management projects. This has attracted environmentally conscious customers and has become a leader in sustainable practices in the industry (Vorecol, 2024).

Unilever has integrated sustainability into its product lines. The company's sustainability plan, launched in 2010, aimed to halve its environmental impact and increase its positive social impact by 2020. One of the key results was the introduction of the personal care brand Love Beauty and Planet, which uses recycled plastic and water sparingly in its production process. As a result, Unilever's sales grew by 20% in one year, demonstrating the strong market potential of eco-innovation. Integrating sustainability principles into innovation processes and manufacturing eco-friendly products is a competitive advantage and a prerequisite for success in today's global market. One of the key trends today is the increasing integration of technology and the digitalization of innovation processes. Technology is crucial in driving innovation from artificial intelligence and machine learning to virtual and augmented reality. Technologies are becoming more progressive and influential, and enterprises are gaining new opportunities to realize their full potential to improve innovation processes, create new competitive advantages, and develop.

Transforming its business model, General Electric (GE) embarked on a strategy to integrate digital technologies into its operations. By investing in the Internet of Things (IIoT), GE sought to use data obtained from its machines to improve efficiency and innovation. This change was revolutionary, as operational efficiency increased by 10%. GE's success shows that digital transformation is not just an opportunity but a necessity in today's competitive environment.

Starbucks analyzed consumer priorities using a mobile app, improved promotions and optimized the inventory management process, which led to a 30% increase in sales revenue from its loyalty program alone (Vorecol, 2024).

Today, AI is used to optimize business processes by automating repetitive ("routine") tasks, generating ideas based on machine learning algorithms, quickly processing large data sets, predicting future results based on analysis, etc. According to McKinsey & Company, using artificial intelligence technologies to optimize business processes has doubled compared to 2017. It is worth noting that recently, AI has gone beyond solving standardized tasks; more and more companies are using it to solve higher-level strategic initiatives that help increase business value (Camilo Quiroz Vazquez, Michael Goodwin, 2024).

The main benefits of using AI technologies in business processes are increasing efficiency and productivity, optimizing decision-making, saving money, improving customer interaction, and stimulating innovation (Fig. 5).

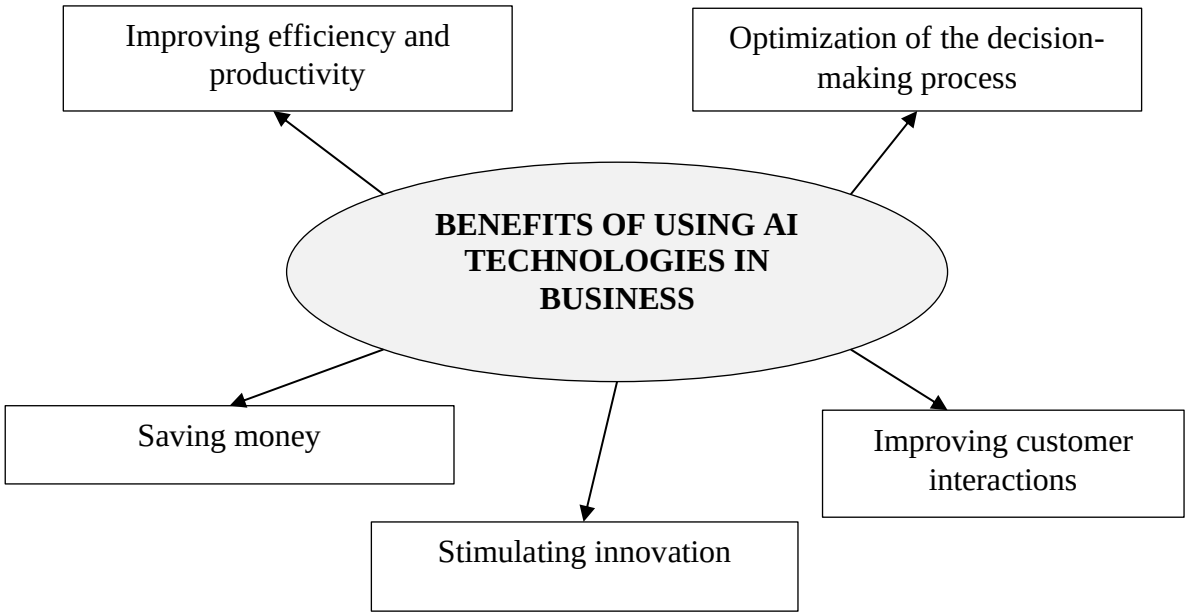


Fig. 5. Benefits of using AI technologies in business processes
Source: summarized by the author based on (Gibson K., 2024)

1. Increasing efficiency and productivity by automating repetitive routine tasks, optimizing workflows, and formulating conclusions based on data analysis. According to the consulting company McKinsey & Company, AI technologies have the potential to automate some of the functions of personnel that take up from 60 to 70% of their working time.
2. Optimizing the decision-making process. By analyzing large data sets, AI makes it possible to identify non-obvious patterns and trends, contributing to making more informed strategic decisions and significantly reducing the likelihood of errors. According to a Deloitte survey, 59% of managers claim that AI allows them to obtain more practical information from analytical data.
Modern businesses are already taking advantage of this advantage. For example, oil and gas company Shell uses AI-based predictive analytics to optimize the process of choosing where to drill for oil. In healthcare, IBM Watson uses AI to analyze patient data and medical literature to provide doctors with evidence-based treatment options and help them choose the most effective cancer treatments.
3. Increased cost savings. AI offers many tools to save financial resources by automating routine tasks, predicting equipment maintenance needs, optimizing supply chains and inventory management, and increasing energy efficiency by analyzing usage patterns and adjusting energy consumption (Gibson K., 2024).
4. Improved customer interactions. AI technologies provide personalized and effective customer communication, help prioritize consumer needs more accurately, and predict customer preferences and needs changes (Olga Maslak, Natalya Grishko, Petro Pererva, Mariya Maslak, Yaroslava Yakovenko, Olha Hlazunova, 2021).
For example, one of the leading sellers of decorative cosmetics, Sephora, uses AI as a virtual artist, an augmented reality tool that allows customers to select and try on makeup. It analyzes facial features and skin tones to provide personalized recommendations for products users can purchase in the application.

5. Stimulating innovation. AI is a catalyst for innovative ideas, which helps accelerate the development of new or upgraded products and optimize the process of managing innovation activities (Gibson K., 2024).

According to the Boston Consulting Group, 91% of innovation leaders actively use AI to identify new business opportunities, and 92% use it to make innovative decisions. Amazon, Google, and Microsoft are already developing business models to offer remote AI as a cloud utility.

Modern scientists have identified the main components of innovation activity in which AI technologies can be effectively used (fig.6).

1. Building an innovative business model. By processing large amounts of data, AI technologies help identify the most investment-attractive business models and predict the selected model's effectiveness.

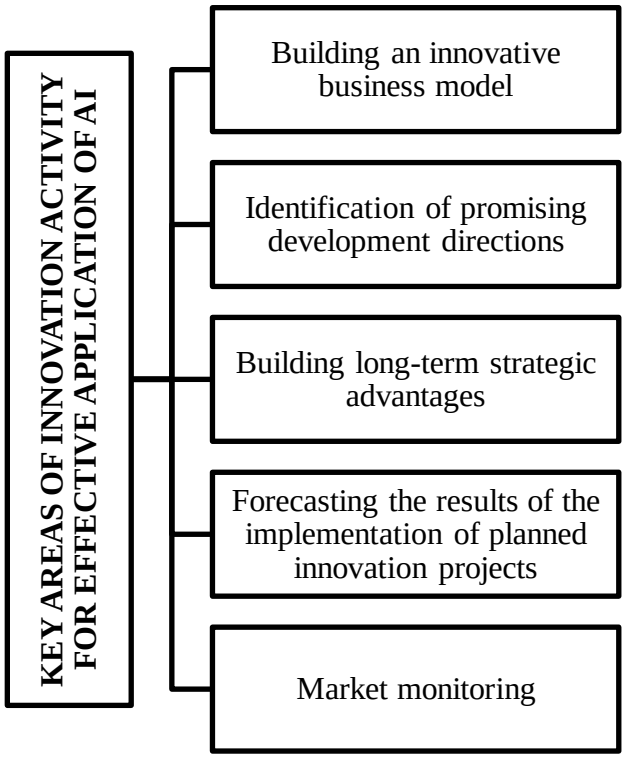


Fig. 6. Key components of innovation activity in which AI technologies are effectively applied
Source: summarized by the author based on (Xavier Ferràs, 2024)
https://dobetter.esade.edu/en/AI-business-innovation

2. Determining promising development directions. AI technologies make it possible to determine the industries currently receiving the most attention, contributing to the development of market technologies and products that will be in demand shortly.

3. Forming long-term strategic advantages. Using predictive models built based on retrospective analysis, AI technologies make it possible to determine the strategic vectors of development of major competitors and, accordingly, to form sustainable competitive advantages in the long term.

4. Forecasting the results of the implementation of planned innovation projects.

5. Market monitoring. AI can analyze data from a huge number of sources, which provides instant analysis of brand perception, contributes to the timely identification of new trends in the market, and successful consumer segmentation, which ensures high adaptability and effectiveness of the company's

innovation strategy (Xavier Ferràs, 2024).
Artificial intelligence is becoming a tool used in all areas of society's socioeconomic life, particularly business. Due to its effectiveness in analysis, forecasting, and the formation of management decisions, AI contributes to increasing productivity, optimizing costs, rationalizing the use of resources, and managing human resources. In 2024, artificial intelligence continues its spread in business, which leads to radical changes in the global economic landscape as enterprises increasingly determine the potential for the development of AI. According to McKinsey & Company, the percentage of companies using AI in at least one business function has increased from 20% in 2017 to 72% in 2024 (fig. 7).

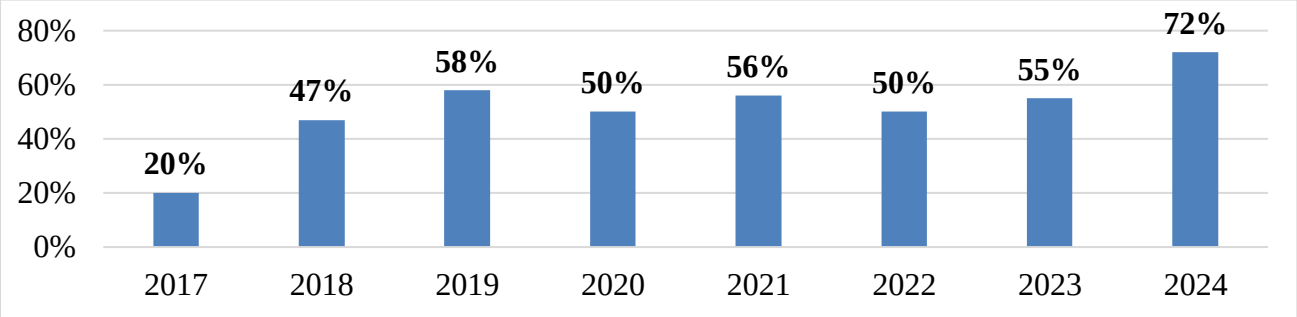


Fig. 7. Percentage of companies using AI in at least one business function (according to McKinsey & Company survey)
Source: based on (Anthony Cardillo, 2024)

In 2024, companies will start massively adopting AI technologies in their operations and derive real business value from them. Expectations for the impact of AI are very high, with entrepreneurs predicting that AI will lead to global changes in their industries in the coming years. In 2024, the AI market exceeded 184 billion USD, a significant jump of almost 50 billion compared to 2023. The AI market is expected to maintain high growth rates, reaching 826 billion USD by 2030 (fig. 8).
Artificial intelligence is used in many business processes, and the benefits of its implementation can be systematized as follows. AI helps to expand human creativity and open up new perspectives. Artificial intelligence technologies are actively used to create and analyze innovative ideas and help find and systematize information. Artificial intelligence can automate routine and complex work to increase speed and efficiency, save time, and increase productivity (Jesse Nieminen, 2024).

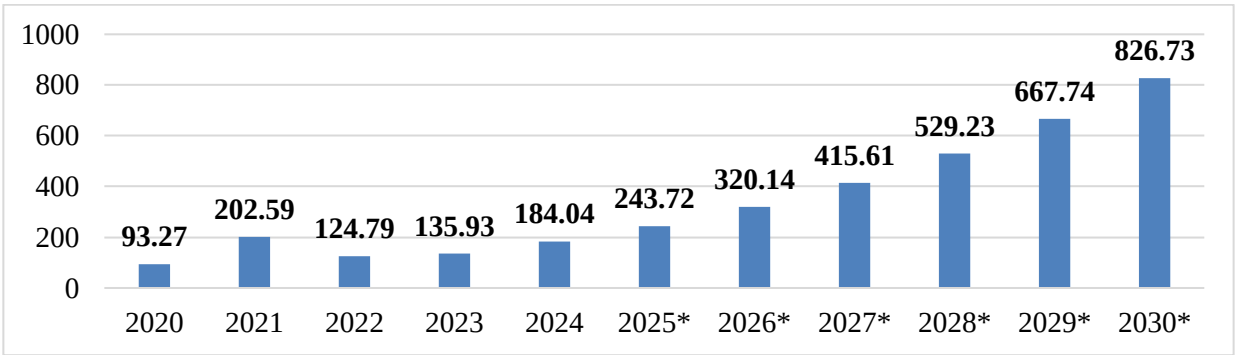


Fig. 8. Global Artificial Intelligence (AI) Market Size from 2020 to 2030, USD Billion

(* – Forecasted Values)
Source: based on (Anthony Cardillo, 2024)

AI is most widely used in improving the following business processes: customer service, cybersecurity, fraud prevention, and customer relationship management (Fig. 9).

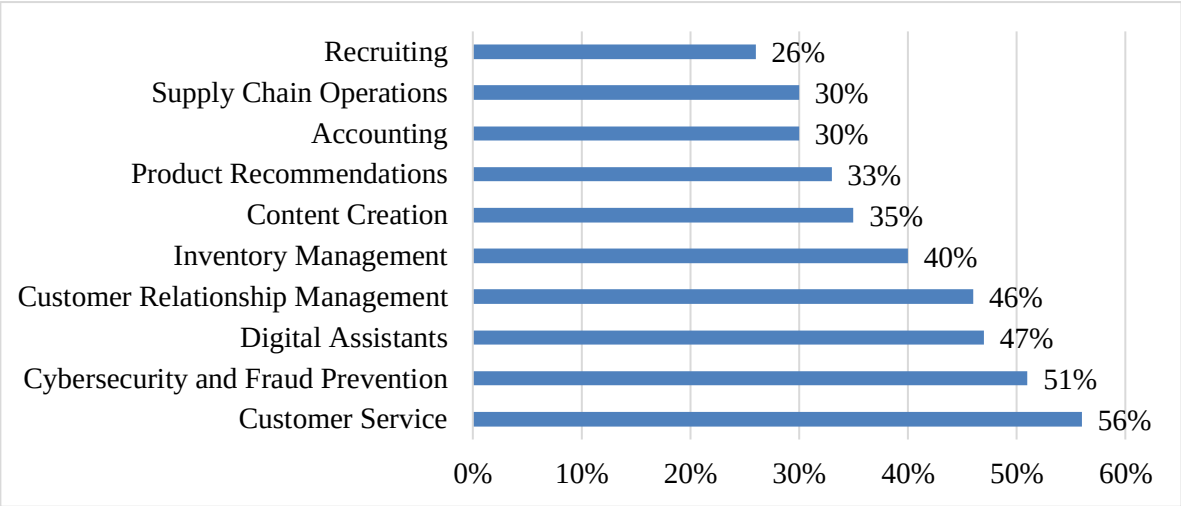


Fig. 9. Use of AI in business operations, %
Source: based on (Anthony Cardillo, 2024)

At the same time, statistical data demonstrate that AI technologies bring the most significant benefits to businesses in increasing product functionality, improving security, creating new products, and boosting innovation (fig. 10).

On September 19, 2024, Tortoise Media released its fifth Global AI Index report, which assesses the potential of AI in 83 countries using a broad set of indicators. This year, 122 indicators were used across seven sub-groups: talent, infrastructure, work environment, research and development, government strategy, and commercial ecosystem, which are then combined into three main pillars: adoption, innovation, and investment.

The United States and China continue to lead the way in developing, investing, and deploying AI technologies, driven by vast resources, talent, infrastructure, significant R&D funding, and successful commercialization of their results (Shivani Singh, 2024).

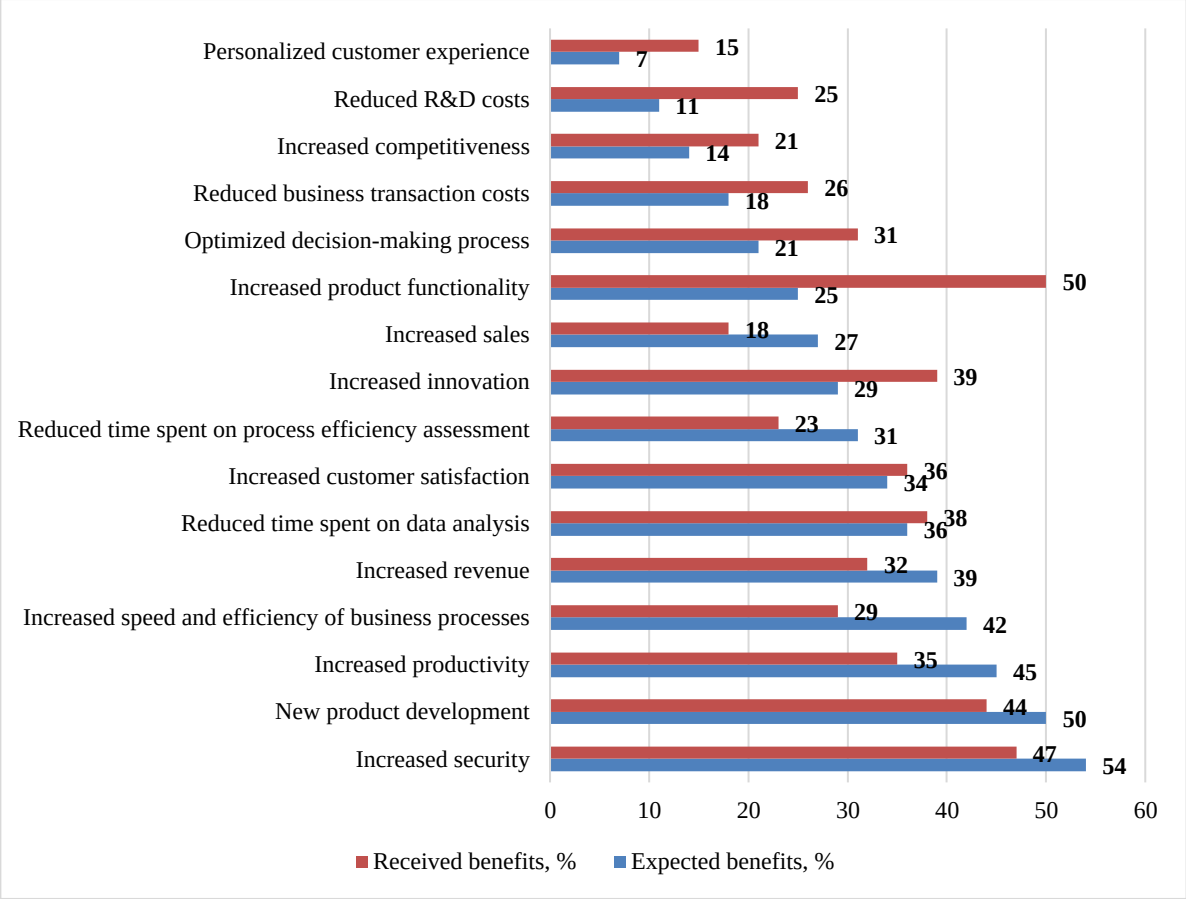


Fig. 10. Expected and achieved benefits from using AI in various business processes, %
Source: constructed by the author based on (Statista, 2024)

Silicon Valley alone is home to some of the industry's most prominent players, including OpenAI, Google, Meta, and Anthropic. These companies have contributed to leading products, including GPT-4, DALL E-3, Gemini, Llama 2, and Claude 3. Investment in US AI is highly significant, with $31 billion raised in 1,151 deals in 2023. The top three deals were from Anthropic, Lightmatter, GreyOrange, and xAI (Tim Keary, 2024).

China attracted $95 billion in private investment in AI technology in 2023. Tencent, Huawei, and Baidu are the industry leaders in the country; for example, Tencent is the Hunyuan Model (LLM) developer, a Chinese alternative to ChatGPT. It is worth noting the significant government investment in AI in China.

Singapore retains third place in the ranking due to the intensity of the use of AI. The country leads in relative indicators, particularly in AI talent per capita, creating competition for world leaders in infrastructure.

Despite fierce competition, the United Kingdom remains fourth, demonstrating high human resource potential in AI and a favorable regulatory environment.

One of the significant changes in the Global AI Index in 2024, France's stunning rise to fifth place, was driven by a robust ecosystem, recent advances in open-source large language model (LLM) research, and significant government support. Mistral, France's national AI champion, competes against giant models from the United States and China to showcase the country's capabilities.

Germany (7th place in the ranking) has also shown a gradual but steady growth since 2021, driven by improvements in infrastructure and research. However, not all countries are seeing positive trends, with Israel (8th place) and Canada (9th place), historically high-growth AI countries, declining in their rankings in 2024 (Tim Keary, 2024).

India entered the top ten for the first time in 2024, thanks to its highly skilled workforce in the AI sector. However, India needs help to retain talent as many of its top AI experts have moved abroad.

By 2024, India is set to lead the world in scale and pace of business AI adoption (59%). The United Arab Emirates is the next largest market, with 58% of companies using AI, followed by Singapore at 53%. The United States has a lower adoption rate, with only 33% of companies using AI (fig. 11).

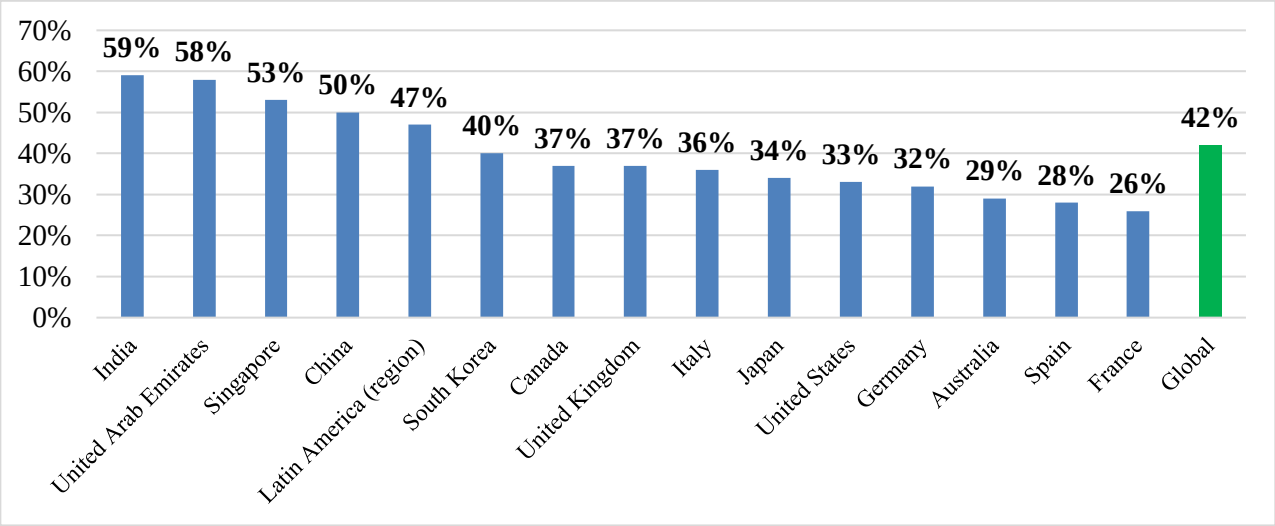
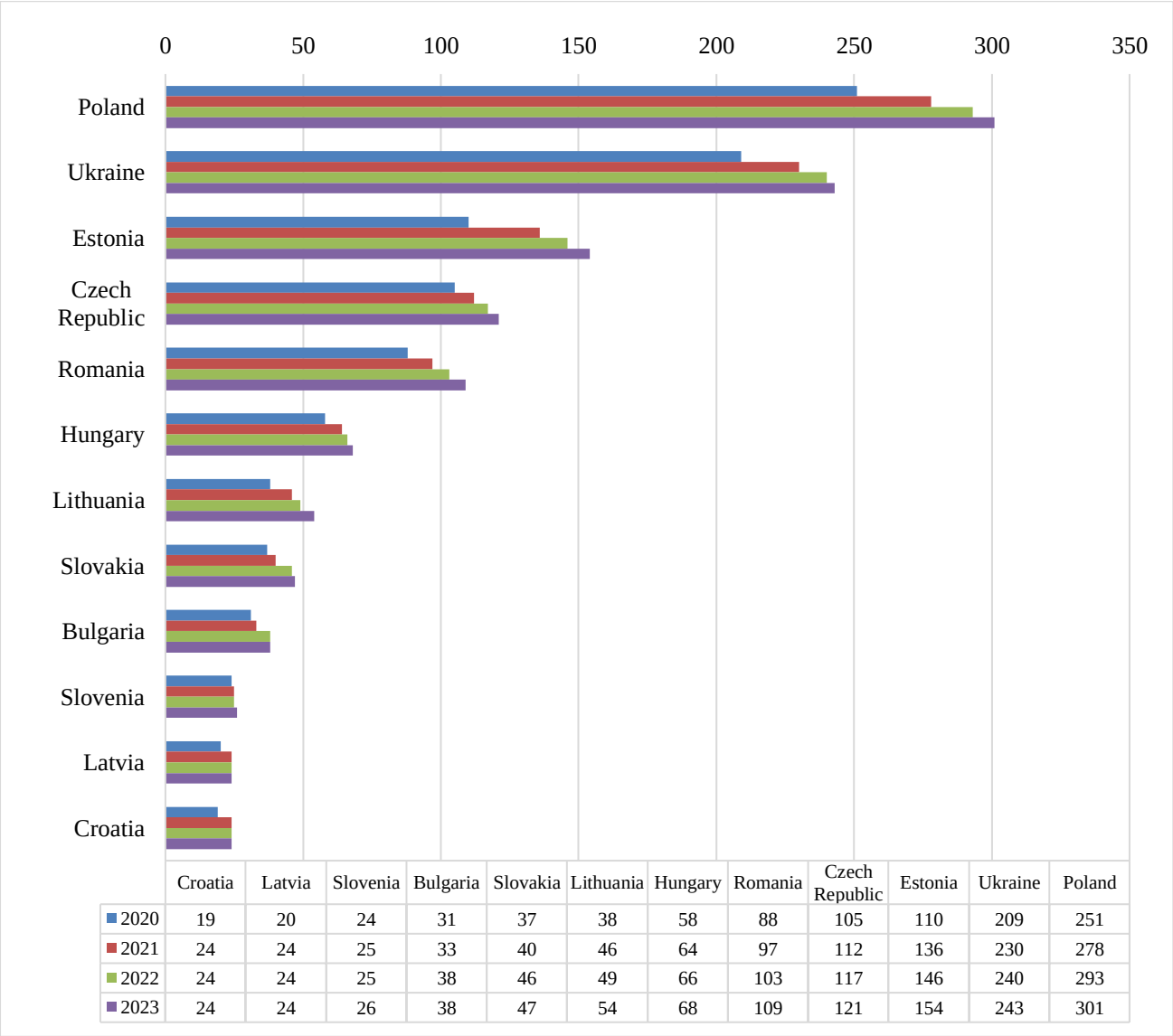


Fig. 11. Global adoption of AI in different countries of the world, %

Source: constructed by the author based on (Statista, 2024)

A notable finding of the 2024 Global Index is the significant increase in government funding for AI. Saudi Arabia has emerged as a leader in government investment plans, exceeding those of the United States and China. While Saudi Arabia's private sector AI research is still in its infancy, the country's aggressive government investment and strategic focus on AI could be game-changers for AI in the Middle East. The country's expansion of AI is aligned with its broader Vision 2030 goals, which aim to reduce its dependence on oil and diversify its economy through technological innovation. The United States, for its part, has been actively taking steps to counter growing competition from countries like Saudi Arabia, including by increasing investment in semiconductor manufacturing and research projects aimed at strengthening public-private partnerships in AI. China has also responded to these global market changes by increasing public funding for AI infrastructure, talent development, and AI research initiatives.

According to the results of modern analytical assessments, Ukraine ranks second in the number of AI companies among Central and Eastern European countries. Thus, 34 new AI companies have started their activities in Ukraine over the past four years, with the most significant number of startups concentrated in business software, gaming, and marketing. As of the end of 2023, there were 243 AI companies in Ukraine, which corresponds to the second-ranking position among the countries of Central and Eastern Europe (Fig. 12).



	Croatia	Latvia	Slovenia	Bulgaria	Slovakia	Lithuania	Hungary	Romania	Czech Republic	Estonia	Ukraine	Poland
2020	19	20	24	31	37	38	58	88	105	110	209	251
2021	24	24	25	33	40	46	64	97	112	136	230	278
2022	24	24	25	38	46	49	66	103	117	146	240	293
2023	24	24	26	38	47	54	68	109	121	154	243	301

Fig. 12. Number of AI companies in Ukraine and Central and Eastern European countries
Source: constructed by the author based on (The AI ecosystem, 2024)

In first place in this indicator among the CEE countries is Poland, with 301 AI companies. In third place is Estonia, which in 2023 had 154 AI companies. Compared to 2020, the number of AI companies in Ukraine increased by 16.27% (Fig. 13). The highest growth rates among CEE countries during this period were demonstrated by Lithuania (42.11%) and Estonia (40%).

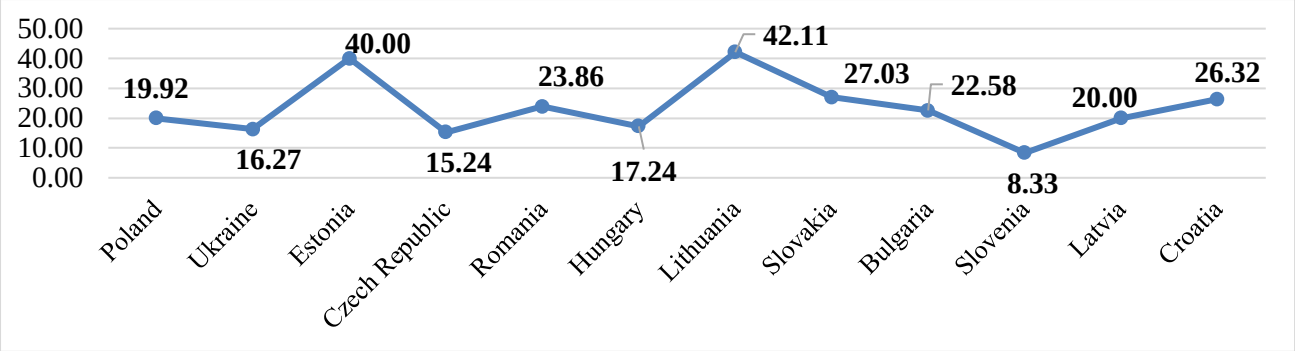
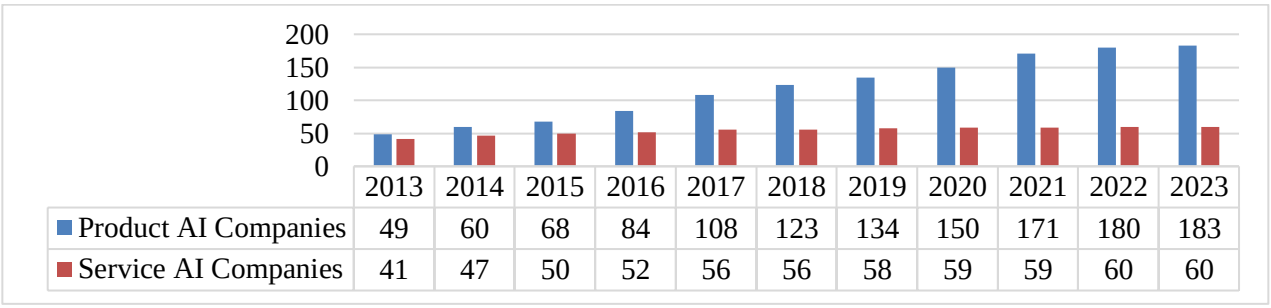


Fig. 13. Growth rate of the number of AI companies in 2023 compared to 2020, %
Source: constructed by the author based on (The AI ecosystem, 2024)

The overwhelming number in Ukraine comprises product companies; in recent years, their number has significantly exceeded that of service AI companies. Thus, since 2013, the number of product and service companies has increased by 283% and 46% (Fig. 14).



	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Product AI Companies	49	60	68	84	108	123	134	150	171	180	183
Service AI Companies	41	47	50	52	56	56	58	59	59	60	60

Fig. 14. Number of food and service companies in Ukraine, 2013-2023
Source: constructed by the author based on (The AI ecosystem, 2024)

The analysis of the structure of venture investment in AI startups indicates significant funding for developing artificial intelligence in most priority industries; in particular, 10.16% of the total investment is directed to defense, 8.57% was invested in robotics, 6.83% in aviation, 6.67% in education, 6.54% in automotive, and 6.47% in medicine (Fig. 15).

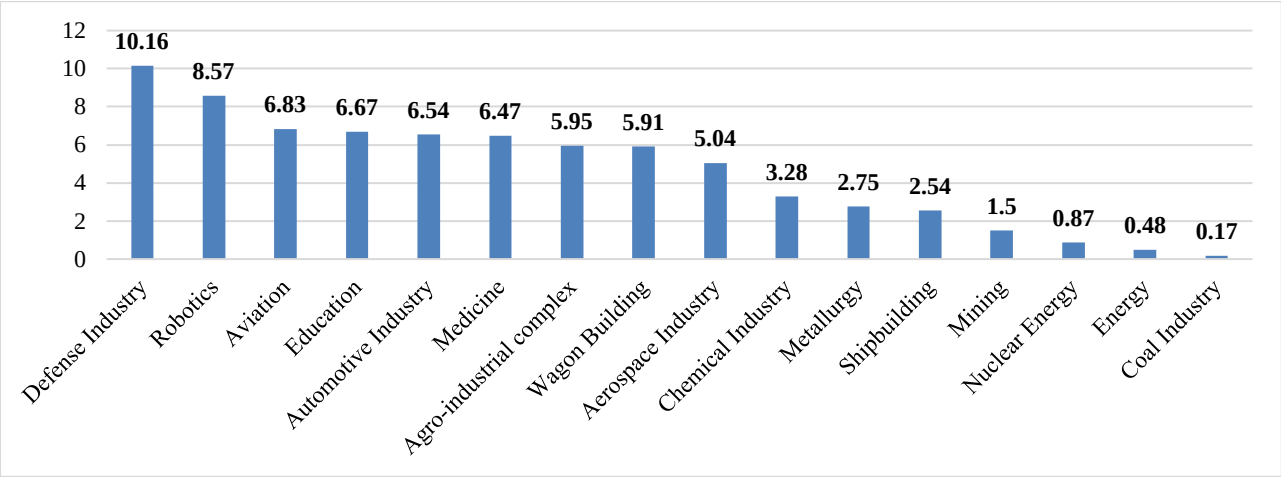


Fig. 15. Share of venture capital investments in the development of artificial intelligence by industry, %

Source: constructed by the author based on (UNIDO, 2024)

Significant state investments and support for AI-based Defense tech startups determine the priority of the defense and military sectors. State investments in the "Drone Army" stimulate the development of the domestic UAV market and technological innovations. The Brave1 state cluster was also launched, which promotes the growth of defense high-tech products and attracts investments. Focusing on developing defense technologies can provide Ukraine with increased international competitiveness in the long term. Starting in 2021, new promising startups in the defense and military sectors have appeared in Ukraine (Table 1).

Table 1. Defense tech startups in Ukraine (AI startups in the defense and military sectors)

Company	Description of main activities	Year of foundation	Investments in the project	Investors
Swarmer	AI-based control center for coordinated drones	2023	$125 тис.	D3 Venture Capital
Osavul	AI-based cyber threat protection	2022	$1 млн	SMRK VC Fund
Zvook	Network of acoustic sensors for detecting air targets	2022	$1 млн	D3 Venture Capital, donor aid, anonymous investors
UA Dynamics	Punisher – strike reconnaissance drone	2021	-	-

Source: constructed by the author based on (The AI ecosystem, 2024)

The Brave1 government coordination platform, launched by key ministries, has ensured the creation of effective communication between the private and public sectors (government, startups, and other stakeholders), as well as domestic and international counterparties (partners, investors, and

corporations) for the creation and implementation of AI-based military innovations. The launch of this large-scale platform has reduced the average duration of an innovation project from five years to several months, ensured the creative cooperation of all participants in the innovation process, and directed grants to promising startups. As a result, this platform has accelerated innovation and introduced a form of public-private partnership (The AI ecosystem, 2024).

Ukrainian companies demonstrate success in developing artificial intelligence technologies even in wartime conditions. The market value of the three most prominent Ukrainian AI startups is estimated at over $14.5 billion, and two Ukrainian AI companies have become unicorns: Grammarly and People.ai. In 2023, Ukrainian innovative companies attracted $10.8 million in venture investments, 31% less than in 2022, which repeats the general global trend. For Ukraine, a significant obstacle to increasing venture financing is full-scale military operations on the country's territory, which significantly increases project risks and reduces the investment attractiveness of domestic projects (Fig. 16).

As a result, Ukraine ranks last in the ranking of Central and Eastern European countries in terms of venture capital investment over the past three years. The leaders are Poland, Lithuania, and the Czech Republic, which attract 12-16 times more financial resources than Ukraine (The AI ecosystem, 2024). However, the venture financing volume for AI startups will show positive dynamics in 2023 (35% more compared to the previous period), entirely consistent with a similar global trend. Over the past four years, the leaders in venture capital investment are Grammarly, Preply, and People.ai, which attracted over $420 million together.

As noted earlier, developing AI technologies is a prerequisite for increasing the competitiveness of individual enterprises, industries, and the national economy. The world's leading economies are actively working on the formation of innovative development strategies based on AI technologies; Ukraine is also developing and implementing a strategy for Thus, in 2019, the Expert Advisory Committee on the Development of the Field of Artificial Intelligence was established, and in 2023, the Ministry of Digital Transformation presented the Roadmap for the Regulation of Artificial Intelligence in Ukraine, developed jointly with the Committee. The Roadmap demonstrates an approach to regulating the development of AI technologies, which is designed to find a balance between business interests and citizens' protection. At the same time, the Ministry of Digital Transformation focuses on a bottom-up approach to regulation, which ensures self-regulation of the artificial intelligence industry, especially at the stages of its formation. This approach is quite popular today in many European countries, mainly the UK, and is characterized by high openness and flexibility. One of Ukraine's essential priorities in AI is the development of technologies that provide the ability to carry out autonomous navigation (without using GPS), collect information, and detect and identify weapons (Goncharuk, 2024).

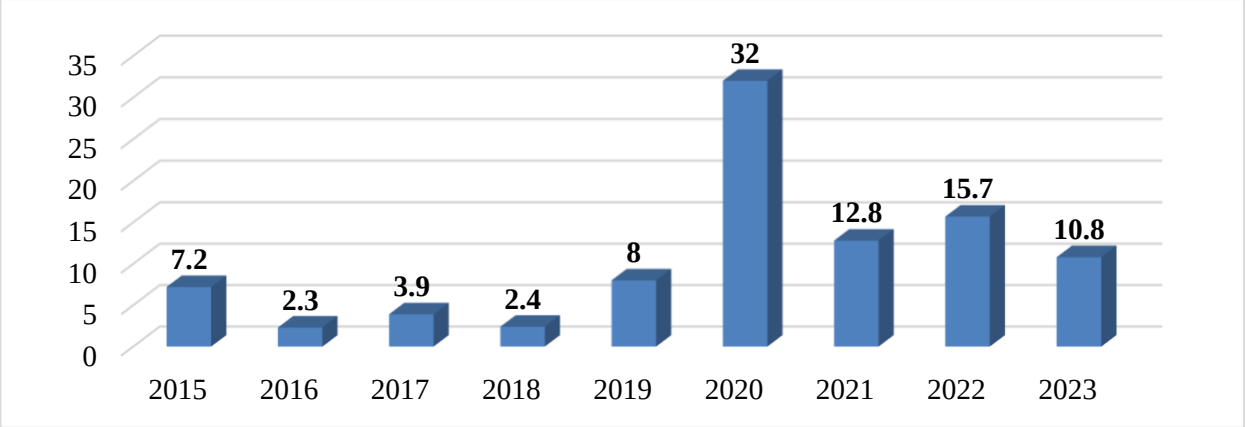


Fig. 16. Volumes of venture investment in innovative and active enterprises of Ukraine, million US dollars

Source: constructed by the author based on (The AI ecosystem, 2024)

The second priority is AI, which can identify disinformation and the botnets that spread it, tools for rapid detection of deepfakes created using generative artificial intelligence. Another critical priority is logistics. The tasks in this area are developing AI technologies that can help plan maintenance, prevent shortages in military warehouses, and predict potential obstacles to replenishment of military supplies based on modeling of the operational environment.

Artificial intelligence for information and communication technologies in cybersecurity and defense. In this area, AI technologies can help ensure connectivity to enemy communication networks and enhance electronic warfare (EW) operations, strengthen data encryption, etc (Goncharuk, 2024).

Thus, the key vector of AI development in Ukraine today is the development and implementation of AI in the security and defense sectors. This includes legislation to ensure transparency, standardization, and simplified protocols for licensing and import.

The use of AI in this area is essential for increasing awareness, readiness, and capabilities during war, in particular through simulation of combat training scenarios, video surveillance monitoring, reconnaissance, and damage assessment, as well as domestic production of dual-use goods such as thermal cameras, sensors, and drones. Ukraine has significant potential for successful AI development, mainly due to a robust IT sector, intellectual capital, state support, and active development of public-private partnerships.

References

1. Minkovska A.V., Molchanov A.S. Theoretical aspects of innovative management in increasing the efficiency of an agricultural enterprise. Business-inform. 2023. No. 8. P. 295-300.
2. Camilo Quiroz Vazquez, Michael Goodwin. What is artificial intelligence (AI) in business? 2024. URL: http://surl.li/plnavz
3. Shovkun-Zablotska L.V. Formation of an effective mechanism of innovation management at enterprises. Scientific notes. 2024. No. 36. P. 281-289.
4. What are the emerging trends in innovation management that will shape the future of business? Vorecol. 2024. URL: https://vorecol.com/blogs/blog-what-are-the-emerging-trends-in-

innovation-management-that-will-shape-the-future-of-business-130918
5. Camilo Quiroz Vazquez, Michael Goodwin. What is artificial intelligence (AI) in business? IBM, 2024. URL: http://surl.li/plnavz
6. Gibson Kate. 5 Key Benefits of Integrating AI into Your Business. 2024. URL: https://online.hbs.edu/blog/post/benefits-of-ai-in-business
7. Olga Maslak, Natalya Grishko, Petro Pererva, Mariya Maslak, Yaroslava Yakovenko, Olha Hlazunova. Artificial intelligence as a key driver of business operations transformation in the conditions of the digital economy. IEEE 20th International Conference on Modern Electrical and Energy Systems (MEES). 2021. URL: https://ieeexplore.ieee.org/document/9598744
8. Xavier Ferràs. Using technology to enhance innovation isn't new but AI is a potential game-changer. New research outlines seven areas where companies can best harness its power. 2024. URL: https://dobetter.esade.edu/en/AI-business-innovation
9. Anthony Cardillo. How Many Companies Use AI? (New Data). 2024. URL: https://explodingtopics.com/blog/companies-using-ai
10. Jesse Nieminen. Is AI the Future of Innovation Management? 2024. URL: https://www.hypeinnovation.com/blog/is-ai-the-future-of-innovation-management
11. Statista. 2024. URL: https://www.statista.com/topics/3104/artificial-intelligence-ai-worldwide/
12. Shivani Singh. Who is Leading Global AI? Insights from the Tortoise Global AI Index 2024. URL: https://www.readipwave.com/who-is-leading-global-ai-insights-from-the-tortoise-global-ai-index-2024-2/
13. Tim Keary. Top 10 Countries Leading in AI Research & Technology in 2024. URL: https://www.techopedia.com/top-10-countries-leading-in-ai-research-technology
14. Mapping the use of artificial intelligence in priority sectors and the competitiveness of Ukraine. UNIDO REPORT. AUGUST 2024. URL: https://www.unido.org/sites/default/files/unido-publications/2024-08/AI_Ukraine_0.pdf
15. The AI ecosystem of ukraine: talent, companies, and education. AI-HOUSE-x-Roosh, 2024. URL: https://aihouse.org.ua/wp-content/uploads/2024/01/AI-Ecosystem-of-Ukraine-by-AI-HOUSE-x-Roosh-ENG.pdf
16. Goncharuk Vitaliy. Russia's War in Ukraine: Artificial Intelligence in Defence of Ukraine. 2024. URL: http://surl.li/xlnwlm

ARTIFICIAL INTELLIGENCE IN DIGITAL BRANDING OF TERRITORIES

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Abstract

This article aims to study artificial intelligence and its impact on the promotion of a territory's brand in the digital environment. The study identifies the main types of artificial intelligence and its subsets. The article considers which artificial intelligence tools are currently most used by marketers. The main digital methods of promoting the brand of a territory are demonstrated and how they are influenced by artificial intelligence are investigated. The disadvantages of using artificial intelligence in territory branding are identified. The author also analyzes how different countries use artificial intelligence and which AI tools are the most popular.

Keywords: *Artificial Intelligence, digital branding. digital marketing, digital methods, territory branding*

Introduction

Artificial intelligence has become an integral part of modern life. It integrates into all spheres of life and helps people in education, creativity, engineering, medicine, economics, manufacturing, marketing, etc. In particular, AI is used in territory branding.

In the context of global competition, territories compete with each other for resources, investments, tourists, etc. In this competition, digital branding comes to the rescue, which involves creating a unique image of a city, region, or country in the digital environment using digital methods and tools. Artificial intelligence, in turn, opens up new opportunities and prospects for creating and promoting a territory's brand.

Objectives

The main goal of this study is to find out how artificial intelligence affects the digital branding of territories. To investigate the types and subsets of artificial intelligence. Identify how artificial intelligence can help promote the brand of territories in the digital environment.

Data and Methods

In conducting this research, general scientific and special methods were used: dialectical, induction and deduction, analysis and synthesis, grouping, comparative analysis, structural and logical, logical generalization of results, and graphical.

Results

Artificial intelligence has been studied by various scientists for years. Each of them offers its own definition and classification of AI. Since there is no unambiguous opinion on the definition of this term, let's consider how it is defined by the Oxford English Dictionary. It defines artificial intelligence as "the capacity of computers, or other machines, to exhibit intelligent behaviour". This means AI systems appear to think, learn and act like humans and in some cases exceed the capabilities of humans. AI systems can analyse vast amounts of data, solve complex problems, make decisions and perform creative tasks." (World Travel & Tourism Council, 2024, p. 7)

Artificial intelligence imitates the human mind and has different functions and capabilities. Depending on this, it is divided into different types, as shown in Table 1.

Table 1. Types of artificial intelligence

AI classification	Types of artificial intelligence
1. Based on Capabilities	Narrow AI (Weak AI; Artificial Narrow Intelligence; ANI)
	General AI (Strong AI; Artificial General Intelligence; AGI)
	Superintelligent AI (Artificial Super intelligence; ASI)
2. Based on Functionalities	Reactive Machines
	Limited Memory
	Theory of Mind
	Self-aware AI

Source: compiled by the author based on (Khan, 2021; Dhokare, 2021; Shopify Staff, 2024; Kumar, 2024; Johnson, 2024)

As we can see from Table 1, artificial intelligence is divided into different types (Khan, 2021; Dhokare, 2021; Shopify Staff, 2024; Kumar, 2024; Johnson, 2024) depending on capabilities and functionality. Depending on the capabilities, there are three types of artificial intelligence:

- Narrow AI (Weak AI; Artificial Narrow Intelligence; ANI).

We encounter it most often. This type of artificial intelligence is designed to perform narrow, specific tasks. It does not have the ability to learn, so it cannot use its knowledge in new situations.

Examples of ANI include virtual assistants, chatbots, spam filters, facial recognition software, website analytics tools, playing chess with a computer, etc.

- General AI (Strong AI; Artificial General Intelligence; AGI).

This type of artificial intelligence is similar to the human mind. It is capable of learning, solving problems, reasoning, etc. General artificial intelligence imitates human thinking and can reproduce human multifunctional abilities.

AGI is used to write original articles, compose music, create pictures and videos, and more. It can also answer complex questions and solve important problems.

- Superintelligent AI (Artificial Super intelligence; ASI)

This is a theoretical type of artificial intelligence that may become a reality in the future. It will be able to surpass human intelligence by using huge amounts of data. Artificial superintelligence will be able to create new products and inventions that people can't even imagine and help solve complex problems.
Looking at the functionality, there are 4 types of artificial intelligence:

- Reactive Machines.

This is the earliest and simplest form of artificial intelligence. These systems have no memory and cannot learn. They only reproduce programmed scenarios. Reactive machines cannot analyze and adapt to new situations.
Examples of reactive machines are chess-playing programs (e.g. Deep Blue), rule-based games, chatbots, traffic management systems, recommendation systems, etc.

- Limited Memory

These systems are a bit more complex than jet engines. A limited-memory AI can collect data and make decisions based on it. That is, it is a type of AI capable of learning from acquired data.
Examples of AI with limited memory include driverless cars (they use algorithms that connect to video cameras and sensors and allow them to navigate the road), advanced email spam filters (which can analyze previous interactions with the sender), smart home devices (e.g., lighting systems, water heaters, security systems), industrial robotics, etc.

- Theory of Mind

This type of artificial intelligence is more advanced. It is not only capable of learning and making decisions, but also begins to interact with people's thoughts and emotions. Researchers are still working on its creation. It is expected to make a significant leap in capabilities and will truly understand people, their intentions and needs.

- Self-aware AI

This type is theoretical, its creation is planned in the future. It is assumed that self-aware artificial intelligence will have its own consciousness and feelings. It could become so similar to the human brain that it would develop self-awareness, have its own emotions and desires.
We can also separately distinguish 9 subsets of artificial intelligence (Keserer, 2024; Kumar, 2024; Muzammil, 2024), which are shown in Figure 1.
Let's consider each subset of artificial intelligence separately:

- Machine learning (ML).

This is a type of artificial intelligence that can learn on its own based on data. It can perform actions on its own without human assistance.

- Deep learning.

This type of artificial intelligence uses many levels of neural networks. It mimics the human brain and learns from large amounts of data. It can be used for image recognition, voice control, etc.

- Natural Language Processing (NLP).

This artificial intelligence technology allows us to process and understand human speech. Thanks to NLP, we can use our voice to address programs (such as Siri and Google), search for queries in search engines, etc.

- Robotics.

This is a type of artificial intelligence used to control physical objects - robots. Robots are programmed to perform certain actions automatically or semi-automatically.

- Expert Systems.

These artificial intelligence systems depend on human knowledge and are programmed based on human expertise. An example of such a system is the correction of spelling mistakes in the Google search box.

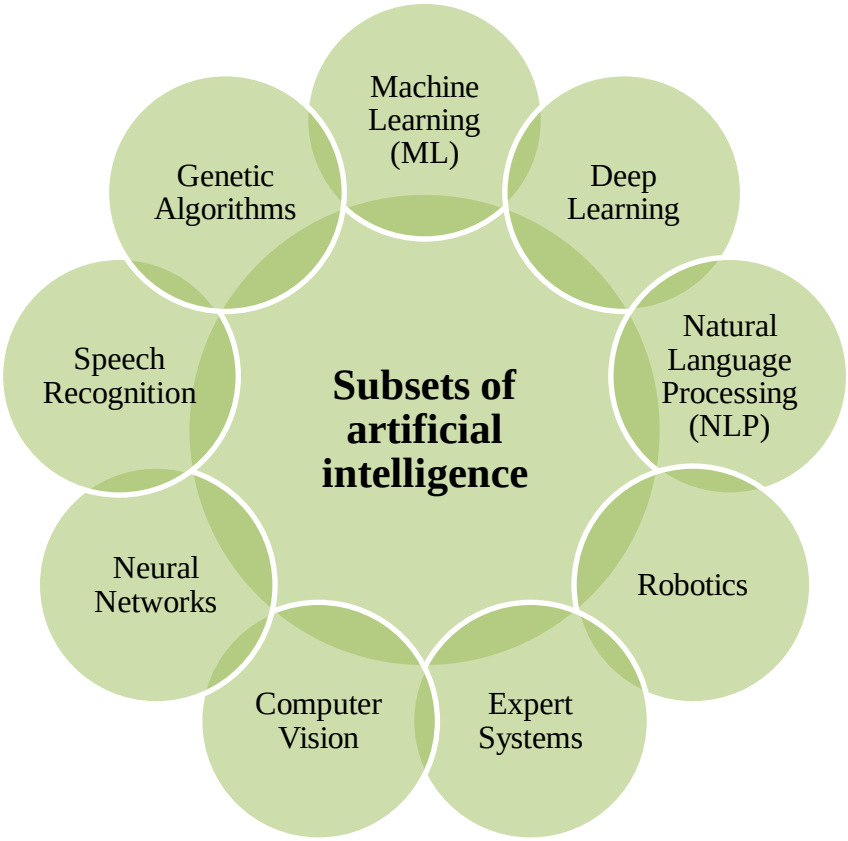

Fig. 1. Subsets of artificial intelligence
Source: compiled by the author based on (Keserer, 2024; Kumar, 2024; Muzammil, 2024)

- Computer Vision.

This technology helps machines detect, track, and analyze images.

- Neural Networks.

This subset of artificial intelligence models processes similar to the human brain. They consist of interconnected neurons or elements that process information, learn from examples, and can solve various tasks.

- Speech Recognition.

This technology allows computer systems to convert sound signals (speech) into text.

- Genetic Algorithms.

This is a powerful tool for solving optimization problems that uses the mechanism of natural selection and evolution to find solutions.

Thus, artificial intelligence finds application in many areas, including marketing. Its implementation in marketing activities allows (DeLegge, 2024; Popov, 2024):

- automated creation and optimization of content, data analysis, and audience segmentation;
- make decisions based on the analyzed data, identify trends and opportunities, anticipate risks, make forecasts and increase the effectiveness of marketing campaigns;
- improve personalization and interaction with the audience and make targeted advertising;
- automate the purchase and placement of digital advertising;
- use chatbots, virtual assistants, augmented reality (AR) to interact with customers, etc.

According to HubSpot's AI Insights for Marketers 2024, nearly 75% of marketers believe that artificial intelligence will become a workplace staple in the coming years.

Marketers most often use the AI tools shown in Figure. 2.

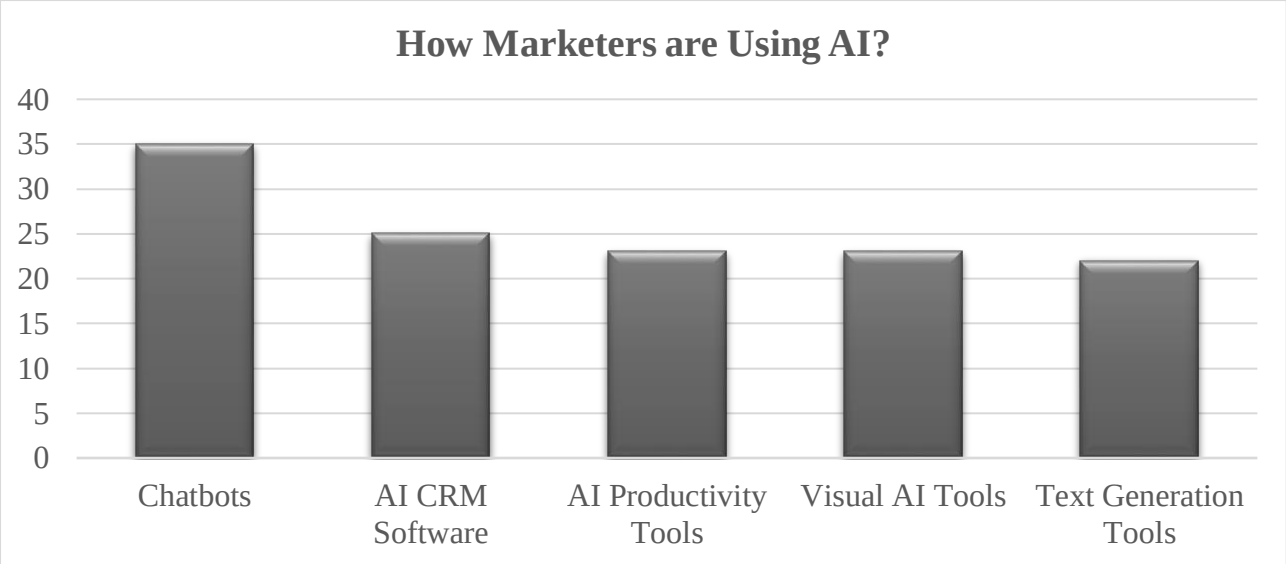

Fig. 2. Top tools among marketers
Source: (HubSpot, 2024)

Marketers are also increasingly using artificial intelligence to create content. (Figure. 3)

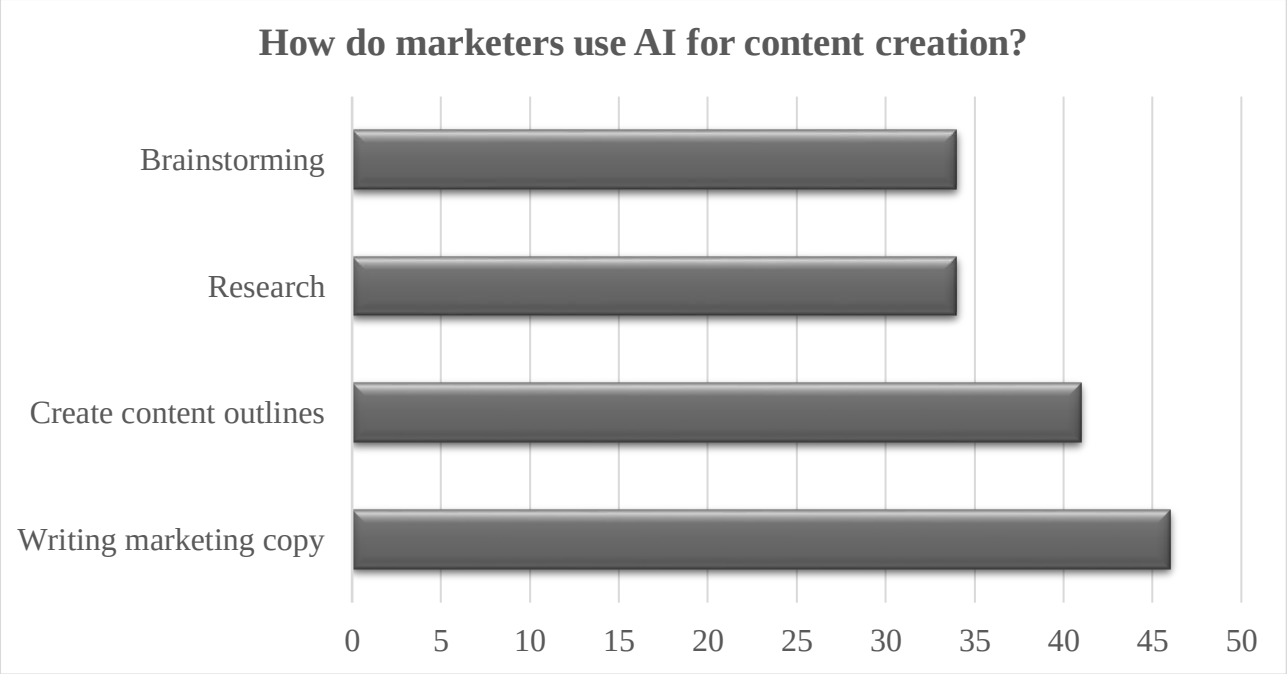

Fig. 3. How do marketers use AI for content creation?
Source: (HubSpot, 2024)

As we can see, artificial intelligence is increasingly integrated into marketing. In particular, it can be used in territory branding.

Territory branding means "the process of creating, promoting and developing a territory brand (village, town, city, region, country) in the digital environment, taking into account its natural-geographical, historical, social, cultural, economic and other features, which creates value for consumers and social, economic benefit for the territory. This process is strategic and creates conditions for the long-term development of the territory." (Iankovets & Levytska, 2024, p. 62)

Territory branding is a powerful tool that helps to promote and popularize a territory, create the desired image, and contribute to the achievement of its development goals. Various digital channels, methods, and tools are used to promote a territory brand. Let's look at the main digital methods of territory promotion, which are shown in Figure 4.

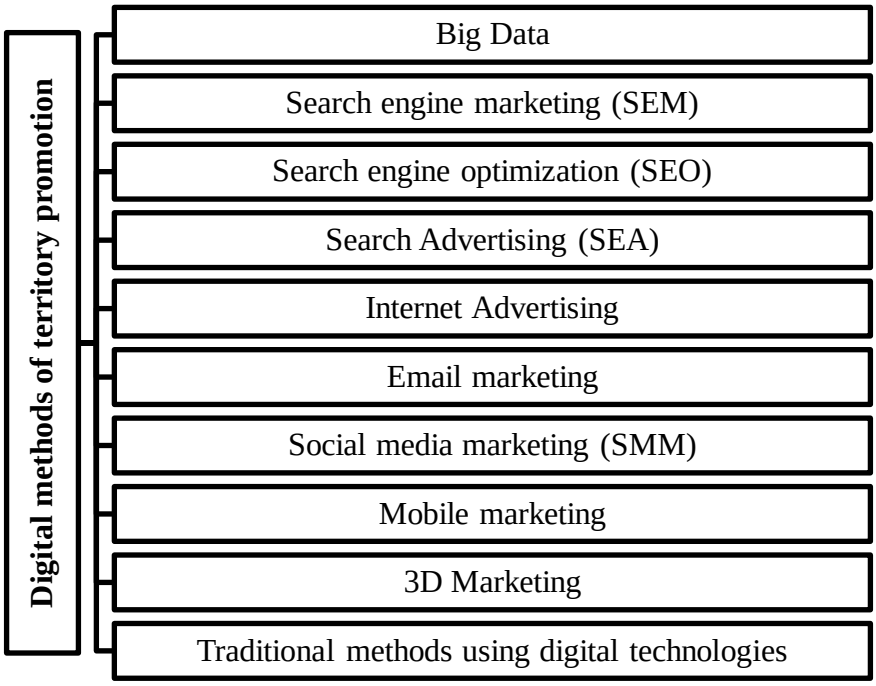

Fig. 4. Digital methods of territory promotion
Source: compiled by the author based on (Iankovets & Levytska, 2024, p. 72)

Artificial intelligence can help to apply digital marketing methods more effectively to promote territories and make people's lives more comfortable. Let us consider how artificial intelligence can be used in each digital method:

- Big Data.

Huge amounts of data help to study people's behavior and needs and create personalized offers based on their analysis. Artificial intelligence allows you to process large amounts of data faster and more efficiently than humans can. It can also be used to perform in-depth data analysis, make predictions, and personalize the processed information. By processing big data with artificial intelligence, you can:

- improve the marketing activities of territories;
- optimize costs and budgets of territories;
- improve urban infrastructure;
- promote business development;
- analyze the behavior and needs of tourists;
- identify trends and make forecasts;
- monitor public opinion on a particular territory, etc.

- Search engine marketing (SEM).

Search engines are the main channel for obtaining information about a territory. Therefore, an important task is to improve the visibility and position of the territory's website in search results. Artificial intelligence can significantly improve SEM for promoting territories, as it allows you to:

- analyze trends, keywords and search queries related to the territory
- automatically generate search engine marketing content that attracts the target audience
- analyze large amounts of data and make recommendations based on it;
- test and optimize advertising campaigns;

- analyze competitors;
- allows users to search for queries in search engines using their voice, etc.

It should be added that SEM is divided into 2 types: SEO and SEA, which will be discussed below.

- Search engine optimization (SEO).

SEO allows you to organically raise the ranking of a territory's website and bring it to the top of search results. Artificial intelligence can be effectively used in SEO because AI helps to:

- analyze trends, keywords and search queries related to the territory and automatically generate content that attracts the target audience
- find and predict the most relevant keywords that will reflect users' search queries
- track competitors and analyze their SEO strategies;
- create content that complies with SEO rules;
- automatically generate meta descriptions, texts, and headlines for SEO promotion;
- ensure better visibility of the site in search engines by analyzing and correcting technical deficiencies;
- track the behavior and requests of website visitors, etc.

- Search Advertising (SEA).

SEA is also a type of online advertising. This type of advertising involves displaying contextual ads in response to a user's targeted search query on a search engine. Artificial intelligence (AI) can significantly increase the effectiveness of Search Advertising, as it allows you to:

- optimize strategies for promoting territories
- automate the creation of advertising campaigns;
- optimize ad rates and control the advertising budget;
- generate content for ads: text, images, videos;
- analyze and predict keywords and popular search queries;
- adapt ads for different segments of the target audience and for different geographical regions;
- test ads and choose the most effective ones, as well as adapt them for voice search;
- attract users who have interacted with the territory through remarketing.

- Internet Advertising.

It allows you to promote and popularize the brand of the territory on the Internet. Online advertising covers all types of advertising used to promote territories on the Internet. It helps to attract the attention of the target audience, engage users, and increase conversions. The use of artificial intelligence in online advertising allows you to:

- create personalized ads by analyzing audience behavior and interests;
- more accurately segment the audience and effectively reach it through targeting, geo-targeting, and remarketing;
- generate content: images, texts, videos, music, etc;
- optimize advertising campaigns and budgets;
- test ads and choose the most effective ones;
- analyze data and make reports on the effectiveness and profitability of advertising campaigns;
- create new advertising formats, such as displaying ads for voice queries in a search engine;
- monitor feedback and comments and respond quickly to them;

- develop advertising strategies, forecast and plan advertising campaigns, etc.

- Email marketing.

Promotes the territory through emails. Emails can be used to inform people about events and activities of the territory, its news, conduct email surveys, etc. Artificial intelligence increases the effectiveness of email marketing by helping to

- generate content: texts, headlines, images for emails;
- analyze and segment the database;
- adapt (personalize) emails to different segments of the target audience;
- automate email campaigns;
- predict user behavior and their actions with emails;
- test emails and optimize email campaigns;
- integrate with CRM systems and other marketing tools;
- generate reports on the effectiveness of email campaigns, etc.

- Social media marketing (SMM).

Promotes the territory's brand on social media, raises user awareness, and improves territory recognition. Artificial intelligence opens up wider opportunities for SMM because it:

- analyzes the target audience more deeply and divides it into segments for more precise targeting;
- generates attractive content for social networks: texts, photos, videos about the territory, etc;
- determines the optimal time for publications;
- ensures quick interaction with subscribers;
- analyzes the effectiveness of SMM by the territory;
- helps to find influencers to popularize the territory;
- allows you to predict trends and adapt content to them, etc.

- Mobile marketing.

It promotes territories with the help of mobile devices that have access to the Internet or mobile communication. Artificial intelligence improves the efficiency of interaction with users via mobile devices by allowing

- make personalized offers, push notifications, and SMS messages based on the user's location
- create interactive applications that will help users interact with the territory (booking applications, city maps, sightseeing guides, etc.)
- use chatbots to communicate with the audience and provide answers to frequently asked questions;
- analyze user behavior and receive feedback;
- adapt content to different mobile devices;
- offer recommendations to users based on their preferences;
- interact with users on mobile devices through voice search;
- integrate with different platforms for a more coherent mobile marketing experience;
- measure the effectiveness and profitability of mobile marketing and optimize campaigns, etc.

- 3D Marketing.

This innovative method allows you to promote territories using three-dimensional visualization and partial or full immersion effects. In particular, artificial intelligence helps with this, as it allows you to

- generate 3D content: create 3D models of sights and objects, landscapes, etc;
- to make virtual tours, excursions around the territory, as well as its museums, galleries, theaters, etc. using VR and AR technologies
- develop interactive 3D maps of the territory;
- create applications for territories using VR and AR technologies (for example, to show the historical appearance of buildings through a smartphone);
- create filters for social networks using AR technologies;
- create interactive presentations and websites with 3D content;
- engage the audience through gamification;
- integrate 3D solutions into tourism and business, etc.

- Traditional methods using digital technologies.

Traditional methods of territory promotion are digital only if they contain elements (QR code, website address, link to a social media account, etc.) that lead from offline to online. Artificial intelligence allows you to optimize the work with traditional methods because it can

- analyze the audience and identify the most effective traditional methods of promoting the territory;
- generate images and texts for printed materials;
- enhance printed materials with interactive technologies: a QR code can direct users to websites or applications using 3D content and augmented reality;
- track effectiveness by analyzing a number of indicators (conversions, clicks, opens, etc.), etc.

Besides helping to achieve the marketing goals of territories, AI also helps to make them more comfortable for people. It can be used (European Parliament, 2020) to create smart homes and cities, improve infrastructure, create self-driving cars, fight cybercrime and disinformation, ensure the safety of people on the streets, use robots in manufacturing and heavy industry, use artificial intelligence to improve agriculture, public administration, and medicine, etc.

However, it should be remembered that artificial intelligence does not completely replace humans, and despite all the advantages, AI has certain disadvantages:

- high implementation costs;
- patterned thinking, lack of creativity;
- AI can generate false information, so it needs to be carefully checked;
- technical errors in the creation of marketing strategies are not excluded;
- privacy violation - it can collect and process data without people's consent;
- AI can mislead people and damage the reputation of the territory.

In 2023, the International Monetary Fund assessed the AI readiness index of 174 countries. According to this rating, the 10 most prepared countries were identified, as shown in Table 2.

“Singapore ranks first as the country most prepared for smooth AI adoption. The country has invested hundreds of millions of dollars into boosting AI capabilities and supporting national AI strategies. Besides Singapore, northwestern European countries like Denmark (#2), the Netherlands (#4), Estonia (#5), Finland (#6), and Sweden (#1) also scored in the top 10 for AI preparedness.” (Zhu, 2024)

Electronics Hub has analyzed more than 90 of the most popular generative artificial intelligence tools and compiled a report for 2023. (Navarro Rodrigo, 2023) From this report, we see that

- the Philippines has the highest monthly search volume for artificial intelligence tools (5288 searches per 100,000 population). Singapore (3,036 searches per 100,000 population) and Canada (2,213 searches per 100,000 population), as well as the UAE (1,926 searches per 100,000 population) and Australia (1,902 searches per 100,000 population) also have a high interest in artificial intelligence;
- the most popular is text generation. The Philippines is the most text-generating country (5239 searches per 100,000 population). They are followed by Singapore, Canada, the UAE, and Malaysia;
- after text generation, image generation is the most popular. Leaders in image generation are Israel (311 searches per 100,000 population), Singapore (295 searches per 100,000 population), Finland (282 searches per 100,000 population), France (280 searches per 100,000 population) and Norway (277 searches per 100,000 population);
- the leader in sound generation is Uruguay (230 searches per 100,000 population). Chile, Argentina, Peru, and Australia follow;
- video generation is the least used. Singapore has the highest number of video generating users (57 searches per 100,000 population), the UAE (50 searches per 100,000 population) and Cyprus (41 searches per 100,000 population);
- the most popular generative artificial intelligence tools are ChatGPT (65 countries) and Quillbot (61 countries);
- the most popular image generation tool is Midjourney (92 countries).

Table 2. Top Countries for AI Preparedness

Rank	Country	AI Preparedness Index Score (0-1)
1	Singapore	0.80
2	Denmark	0.78
3	United States	0.77
4	Netherlands	0.77
5	Estonia	0.76
6	Finland	0.76
7	Switzerland	0.76
8	New Zealand	0.75
9	Germany	0.75
10	Sweden	0.75

Source: (Zhu, 2024)

As we can see, people in different countries are already actively using artificial intelligence, in particular for content generation. However, the use of artificial intelligence is not limited to the creation of texts, images, audio, and video. It can comprehensively help cities and countries develop and ensure a comfortable life for their population.

Conclusions

Artificial intelligence has become a popular technology used by millions of people every day. In digital territory branding, artificial intelligence opens up new opportunities, as it allows you to perform routine work faster and more efficiently, as it automates and optimizes processes. In addition, artificial intelligence can help create territory development strategies and marketing strategies. It can also be used to attract tourists, investors, and new residents by promoting the territory's brand at the national and international levels. However, one should not blindly trust artificial intelligence - it should complement, not replace, human activity. In addition, we should not forget about the uniqueness and identity of each territory, because artificial intelligence may not take them into account and think in a rather stereotypical way. In addition, its implementation requires significant investments. But despite the drawbacks, the integration of artificial intelligence contributes to the more effective promotion of territories in the global competitive environment.

Thus, the introduction of artificial intelligence into digital branding of territories is becoming an integral part of a modern promotion strategy.

References

1. DeLegge Peter. (2024). How AI Is Transforming Marketing (2024). MarketingHire. Retrieved from https://marketinghire.com/career-advice/how-ai-is-transforming-marketing
2. Dhokare Satish. (2021, June). A study of artificial intelligence types, opportunities & challenges. ResearchGate. Retrieved from https://www.researchgate.net/publication/352056548_A_STUDY_OF_ARTIFICIAL_INTELLIGENCE_TYPES_OPPORTUNITIES_CHALLENGES
3. European Parliament. (2020) (Last updated 2023). What is artificial intelligence and how is it used? Retrieved from https://www.europarl.europa.eu/topics/en/article/20200827STO85804/what-is-artificial-intelligence-and-how-is-it-used
4. HubSpot. (2024). AI Insights for Marketers [New Data]. Retrieved from https://offers.hubspot.com/ai-marketing
5. Iankovets T., Levytska I. (2024). Digital tools for territory branding. Scientia fructuosa. № 4. P. 58-81. https://doi.org/10.31617/1.2024(156)04
6. Johnson Jonathan. (2024). Types of AI with Examples. BMC. Retrieved from https://www.bmc.com/blogs/artificial-intelligence-types/
7. Keserer Ekin. Akkio. (2024). The six main subsets of AI: (Machine learning, NLP, and more) Retrieved from https://www.aalpha.net/blog/subsets-of-artificial-intelligence/
8. Khan Hanif. (2021, September). Types of AI / Different Types of Artificial Intelligence System. ResearchGate. Retrieved from https://www.researchgate.net/publication/355021812_Types_of_AI_Different_Types_of_Artificial_Intelligence_Systems_fossgurucomtypes-of-ai-different-types-of-artificial-intelligence-systems

9. Kumar Aditya. (2024). Types of AI Explained: From Narrow to Super AI. Simplilearn. Retrieved from https://www.simplilearn.com/tutorials/artificial-intelligence-tutorial/types-of-artificial-intelligence
10. Muzammil K. (2024). 6 Subsets of Artificial Intelligence. Aalpha. Retrieved from https://www.akkio.com/post/the-five-main-subsets-of-ai-machine-learning-nlp-and-more
11. Navarro Rodrigo. (2023). Generative AI Global Interest Report. Electronicshub. Retrieved from https://www.electronicshub.org/generative-ai-global-interest-report-2023/
12. Popov Evgeny. (2024). How AI Is Transforming The Marketing Industry. Forbes. Retrieved from https://www.forbes.com/councils/forbestechcouncil/2024/03/21/how-ai-is-transforming-the-marketing-industry/
13. Shopify Staff. (2024). Understanding Types of AI: A Simple Guide for Beginners. Shopify. Retrieved from https://www.shopify.com/blog/types-of-ai
14. World Travel & Tourism Council. (2024). Introduction to AI 2024. Retrieved from https://cdn-dynmedia-1.microsoft.com/is/content/microsoftcorp/microsoft/final/en-us/microsoft-brand/documents/2024-wttc-introduction-to-ai.pdf
15. Zhu Kayla. (2024). Mapped: Which Countries Are Most Prepared For AI? Visual Capitalist. Retrieved from https://www.visualcapitalist.com/mapped-which-countries-are-most-prepared-for-ai/

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