CONTEMPORARY ISSUES OF DIGITALIZATION IN ECONOMICS, MANAGEMENT, EDUCATION

Monograph

Contemporary Issues of Digitalization in Economics, Management, Education

Collective monograph edited by
Iuliia Kostynets

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The monograph examines a central challenge of contemporary socio-economic development, namely how digitalization transforms economics, management, and education under conditions of structural change, uncertainty, and external threats. As technological progress accelerates and artificial intelligence diffuses across sectors, organizations and public institutions face growing pressure to innovate while preserving stability, legitimacy, and long-term performance. Digitalization simultaneously expands opportunities for productivity and competitiveness and increases systemic complexity, because decisions, coordination, and service delivery are increasingly mediated by platforms, data infrastructures, and algorithmic tools. Within this context, digital transformation is conceptualized as a multidimensional socio-economic and institutional process that reshapes management systems, leadership models, entrepreneurial ecosystems, territorial development trajectories, and the operating logic of higher education institutions. Particular attention is devoted to crisis settings, including prolonged security challenges and military threats, where digital technologies function not only as efficiency instruments but also as mechanisms of continuity, adaptation, and recovery.

The monograph is intended for researchers, business executives, managers, policymakers, educators, and graduate students who require a coherent and integrative framework for understanding digital transformation and its implications for organizational resilience, economic development, and educational modernization. By positioning digitalization within the broader agenda of resilience and sustainable socio-economic development, it contributes to scholarly debate, supports interdisciplinary research, and encourages the development of accountable strategies suited to high-uncertainty contexts.

Table of Contents

https://doi.org/10.36690/CIDI-EME
ISBN 978-9916-9320-3-2 (pdf)

https://doi.org/10.36690/CIDI-EME
ISBN 978-9916-9320-3-2 (pdf)

Introduction

The accelerating pace of digital transformation is a defining feature of contemporary socio-economic development, reshaping economic systems, management practices, organizational structures, and educational institutions on a global scale. Digital technologies increasingly mediate decision-making, managerial communication, production, and service delivery, changing how economic actors coordinate, create value, and respond to uncertainty. At the same time, these transformations unfold in an environment marked by geopolitical tension, security risks, and disruptive external shocks, which alter both the direction and the outcomes of digitalization. In this context, digital transformation should be understood not as a purely technical modernization, but as an institutional and strategic process that reconfigures governance, markets, and human capital formation.

For Ukraine, digital transformation has acquired particular systemic significance. Prolonged external military threats, economic contraction, demographic shifts, and large-scale infrastructure disruption have intensified the need for adaptive and resilience-oriented development models. Under such conditions, digitalization becomes a mechanism of continuity for governance, entrepreneurship, education, and territorial development, while also supporting recovery and reconstruction capacities. The Ukrainian case therefore offers a distinctive analytical setting in which digital transformation intersects with war-related constraints, institutional reform, security challenges, and long-term reconstruction priorities.

This monograph is grounded in the premise that digital transformation is multidimensional and cross-sectoral. It simultaneously affects management systems and leadership models, entrepreneurial ecosystems and regulatory frameworks, sectoral and territorial development, markets and security architectures, as well as higher education institutions and the reproduction of human capital. The rapid diffusion of artificial intelligence further amplifies cross-cutting challenges related to competitiveness, governance, ethics, labor

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ISBN 978-9916-9320-3-2 (pdf)

markets, and skills development. Addressing these issues requires an integrated approach that combines insights from economics, management science, institutional theory, innovation studies, regional development, and education policy.

The monograph contributes to academic and policy debates by offering a comprehensive and context-sensitive analysis of digital transformation in economics, management, and education under conditions of heightened uncertainty and external threats. By integrating theoretical perspectives, strategic analysis, and Ukraine-focused case studies, the book demonstrates that digitalization is a socio-economic and institutional phenomenon that produces differentiated outcomes depending on governance quality, security conditions, and the capacity to translate technology adoption into sustainable organizational and societal change.

The monograph consists of four chapters, each examining a core dimension of digital transformation and its implications under contemporary pressures.

Chapter 1 *"Digital Transformation of Management and Leadership"* focuses on the transformation of managerial and organizational systems in the digital era. It examines the digitalization of communication processes within management systems and analyzes how digital tools reshape coordination mechanisms, decision - making practices, and organizational efficiency. Special attention is devoted to the effects of digital transformation on leadership models, including gender dimensions of leadership in business organizations. The chapter further addresses security aspects of organizational management and personnel loyalty in digitally transformed environments, as well as digital tools for managing companies' foreign economic activity, highlighting the growing complexity of managerial decision - making in open and digitized economies.

Chapter 2 *"Digital Economy, Entrepreneurship and Sectoral Transformation"* shifts the analytical focus toward economic processes and business development in the context of digitalization. It explores the development of digital entrepreneurship and the role of tax and regulatory levers in shaping entry, resilience, and scaling of digital

https://doi.org/10.36690/CIDI-EME
ISBN 978-9916-9320-3-2 (pdf)

businesses, with particular emphasis on the Ukrainian case. The chapter also analyzes sectoral digital transformation, including the construction sector and tourism, demonstrating how digital technologies and innovations - such as unmanned aerial vehicles - can support sustainable development, post - crisis recovery, and modernization of traditional industries.

Chapter 3 *"Digital Transformation under War, Security Threats and Territorial Challenges"* addresses the systemic impact of prolonged external threats on digital development. It examines socio - economic development of territories under conditions of military aggression, focusing on structural disparities and the role of digital transformation in enhancing territorial resilience. In addition, the chapter analyzes challenges faced by ICT markets in conditions of external military threats, including vulnerabilities related to infrastructure, cybersecurity, human capital, and institutional stability. Particular emphasis is placed on economic and information security frameworks as critical components of resilient digital ecosystems. The chapter also explores artificial intelligence as a driver of business competitiveness, assessing its transformative potential alongside associated governance, ethical, and strategic management challenges.

Chapter 4, *"Digital Transformation of Education and Artificial Intelligence"* focuses on cross - cutting challenges related to education, human capital, and advanced digital technologies. It presents a strategic analysis of the sustainable development of higher education institutions in the face of digitalization challenges, recognizing universities as key actors in innovation systems and knowledge economies. By integrating education and AI perspectives, the chapter highlights the critical role of skills development and institutional adaptation in the digital era. This section also explores EU best practices on digital transformation, artificial intelligence and inclusion in universities.

This monograph was prepared within the framework of the research project of the National Academy of Management, "Digitalization of Socio-Economic Systems: Current State and Development Prospects" (State registration number: 0122U202056).

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ISBN 978-9916-9320-3-2 (pdf)

The studies presented reflect the project's core directions and aim to clarify how digital technologies transform economic processes, management systems, entrepreneurial activity, territorial development, and education under conditions of structural change, uncertainty, and external threats. The results contribute to the development of theoretical and applied foundations for understanding digital transformation in crisis contexts and support the formulation of evidence-based recommendations for sustainable socio-economic development.

Future research on digitalization in economics, management, and education should shift from documenting technology adoption toward explaining the causal mechanisms through which digital transformation either strengthens resilience or reproduces structural vulnerabilities. Priority should be given to integrative models that connect platform governance, data infrastructures, and AI-enabled decision systems with observable outcomes in productivity, competitiveness, legitimacy, and public trust. Comparative studies across stable and crisis-exposed contexts are necessary to specify how external threats, security constraints, and reconstruction imperatives condition the effectiveness of digital strategies, policies, and organizational reforms. Finally, interdisciplinary scholarship should advance coherent ethical and regulatory frameworks for responsible AI and platform governance, ensuring that digital modernization remains aligned with public values and long-term sustainable socio-economic development.

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Chapter 1
Digital Transformation in Management, Leadership and Entrepreneurship

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Section 1.1. Digitalisation of Communications in the Management System

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Abstract. *Digitalization is redefining administrative management by moving public services from paper-based routines to integrated e-government systems that connect the state, citizens, business, and civil society. This transition responds to declining bureaucratic efficiency and rising expectations for transparency, speed, and participation, while also revealing infrastructure gaps, uneven digital literacy, and cybersecurity vulnerabilities. This study examines e-government as a core instrument of public sector digitalization and clarifies how platforms, data systems, and digital channels reshape service delivery and decision-making. The study uses an integrative literature review and analytical synthesis of Ukrainian and international research. Evidence is systematized across enabling technologies (artificial intelligence, blockchain, big data, cloud computing, Internet of Things), institutional conditions (legal adaptation, personnel upskilling, public-private partnerships), and evaluation criteria operationalized through key performance indicators. The KPI logic covers efficiency, transparency, trust, cost-effectiveness, and inclusiveness as comparability dimensions across jurisdictions over time. E-government enables automation of routine tasks, electronic document management, unified registers, and citizen engagement through petitions and consultations. The Diia case illustrates faster processing, access to digital documents and signatures, and scalable crisis services. Key barriers include connectivity gaps in rural areas, legacy systems, resistance to change, and data protection risks. E-government strengthens administrative capacity when technology adoption is aligned with digital culture, infrastructure modernization, and citizen-centric service design. Future work should test causal effects of specific technologies on service quality, compare inclusion outcomes across regions, and evaluate governance models that balance innovation with cybersecurity and human rights safeguards.*

Keywords: *e-government; public administration digitalization; administrative management; digital platforms; Diia; artificial intelligence; blockchain; big data; cybersecurity; digital literacy; e-participation; digital culture.*

1. E-government as a key element of digitalization of administrative management. Digitalization is an integral part of the modernization of management processes in the public sector. In this context, e-government is a strategic tool that integrates innovative technologies with administrative functions. Its main goal is to create an efficient, transparent and accessible system of interaction between the state, citizens and business.

Modern society is undergoing significant transformations caused by the rapid development of digital technologies and globalization processes. These changes make new demands on public administration, which must be adapted to dynamic challenges and meet the growing expectations of citizens. Traditional bureaucratic methods are losing their efficiency, effectiveness and transparency, which necessitate the transition to digital tools.

The solution of resources issues requires a systematic approach, including infrastructure modernization, training of qualified personnel, and adaptation of legislation and development of criteria for assessing the effectiveness of digitalization. One of the most significant challenges is the lag in the implementation of modern technologies. The use of outdated information systems, limited resources, and low digital literacy significantly slow down public sector reforms.

However, the potential of new technologies such as electronic platforms, artificial intelligence and blockchain, opens up prospects for a significant improvement in the quality of public services.

At the same time, the implementation of digital technologies is accompanied by a number of challenges, including technical, legal, organizational and personnel problems. These technologies not only help to optimize management processes, but also provide a new level of transparency and accessibility of administrative functions.

The modern scientific community is actively researching the processes of digitalization of public administration, which is particularly relevant in the context of global technological change. Innovative technologies, such as artificial intelligence, blockchain and open data platforms, create new opportunities for optimizing administrative processes, increasing transparency and improving the quality of public services. At the same time, the use of these technologies is accompanied by a number of challenges, including technical barriers, cybersecurity risks and the need to increase the level of digital literacy among public sector employees.

Thus, V. D. Syrotin in his research analyses the essence and features of

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ISBN 978-9916-9320-3-2 (pdf)

digitalization in the sphere of public administration, focusing on the importance of digital technologies for improving the procedures and methods of public authorities (Syrotin, 2023).

N. Bondarchuk and N. Dubrova study the current state and prospects of digitalization in public administration, as well as identify the key conditions and factors that contribute to the transformation of this area (Bondarchuk&Dubrova, 2023).

Particular attention is paid to the concept of the digital state, where N. V. Atamanova and P. O. Kotysh focus on digital competencies and technologies that are critical for the effective functioning of the modern state (Atamanova&Kotysh, 2022).

In turn, I. P. Lopushynskyi analyses the latest scientific approaches to the digitalization of public administration, studies the regulatory acts of Ukraine and international documents governing the introduction of information and communication technologies in this area (Lopushinsky, 2018).

The process of Ukraine's formation as a digital state and improvement of the system of state electronic information resources is studied by H. Blinova. The author also emphasizes the importance of digitalization for the development of public administration (Blinova, 2021).

Kolomoyets examines the problems of ensuring human rights and freedoms in the context of digitalization of public administration systems, focusing on the challenges and opportunities that are developing in the process of digital transformation (Kolomoiets, 2023).

These studies provide a thorough analysis of current trends and challenges in the digitalization of public administration, offering a wide range of approaches and solutions for the effective implementation of innovative technologies in the public sector. They highlight the multidimensionality of digitalization issues and reveal the significant potential of modern technologies in the process of public administration reform. At the same time, this topic remains insufficiently researched, which underscores the need for further research.

This study analyses the essence and role of e-government in the context of digitalization of administrative management, with a focus on its impact on the formation of new approaches to communication and management decision-making. The digitalization of administrative processes involves the widespread use of information and communication technologies (ICT) to optimize the activities of public institutions. In particular, this includes the automation of routine tasks, the introduction of electronic document management, and the creation of digital platforms and services that provide citizens with convenient access to public services. The key benefits of digitalization include efficiency through reducing time and resources; transparency which could minimize corruption risks through process automation and accessibility which increase opportunities for citizens to participate in decision-making.

The digitalization of the public sector aims to automate management processes, improve interaction between the state and citizens, and increase transparency. Innovative solutions include: artificial intelligence (AI), which helps to analyze large amounts of data, automate routine tasks and predict the needs of the population; blockchain, which improves the security and transparency of operations, as well as optimizes registration processes; and big data, which allows for the development of management strategies based on analytical data processing.

E-governance is a management system based on the use of digital technologies and provides interactive interaction between government agencies, citizens and businesses (Syrotin, 2023). Its tasks include:

– Digitilization of administrative services: creation of online platforms for submitting applications, registering, obtaining certificates, etc.

– Optimization of communications: transition from traditional to digital document management.

– Development of digital democracy: the possibility for citizens to participate in public policy making through electronic petitions and polls.

E-governance transforms approaches to governance, affecting the following aspects: increased transparency through open access to information and monitoring of public spending; centralization of data through the creation of unified registers and databases that simplify information processing; reduction of administrative burden, as automation of processes allows civil servants to focus on strategic tasks.

The visualisation the interaction of participants in digital governance has been given on Figure 1.1.

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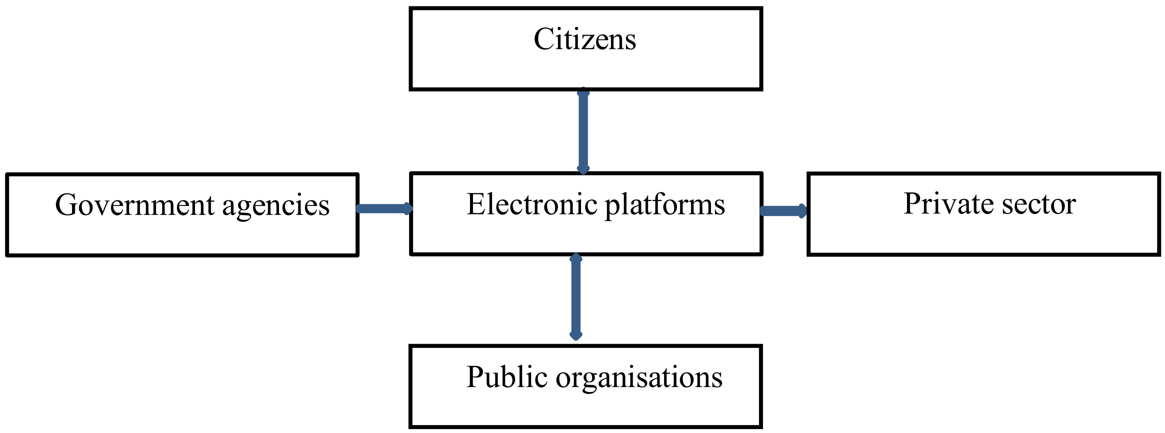

Figure 1.1. Interaction of participants in digital governance
Source: generated by the author

Figure 1.1 demonstrates that citizens have access to public services through integrated electronic platforms that simplify procedures and make administrative services easy to use. Government agencies are introducing digital technologies to automate service delivery, improve management processes, and increase the efficiency of interaction with other stakeholders. The private sector is involved in the development of innovative technological solutions and actively cooperates with government agencies in public-private partnerships to improve the quality of digital governance. Civil society organizations monitor transparency and accountability, promoting openness and efficiency in the activities of public authorities. This diagram illustrates a comprehensive approach to digital governance based on collaboration between key stakeholders.

An example of successful e-governance implementation is the Diia platform in Ukraine, which integrates key government services into the online environment. The Diia platform (an acronym in Ukrainian for "State and Me") is a landmark project for the digitalization of public services in Ukraine. Created by the Ministry of Digital Transformation of Ukraine, it has become one of the most successful examples of the use of innovative technologies in public administration. Launched in 2020, the Diia platform aims to digitize public services, reduce bureaucracy, ensure transparency of processes, and improve citizens' access to public services. This is part of a larger plan. Currently, citizens already have access to a wide range of services, such as: registering newborns through the eBaby service; storing digital documents

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ISBN 978-9916-9320-3-2 (pdf)

(passports, driving licenses); obtaining COVID certificates, social assistance and other services. The functional platform is constantly expanding to include new services, such as online adoption or filing a claim for destroyed property (Bondarchuk& Dubrova, 2023).

For a more detailed look at the benefits of the Diia platform, you should pay attention to the Diia mobile application, which is a platform for storing digitized documents, including passports, identification codes, driving licenses, technical passports, student ID cards, birth certificates, and others. To sign documents in the online format, an electronic signature is used, which is provided through the Diia Signature function. This ensures the convenience and security of the document signing process, which is important for the effective functioning of e- government.

The Diia portal is an important tool for providing public services, such as business registration, subsidies, income certificates, permits, payments for IDPs, and more. In addition, the platform includes a special legal regime called Diia City that supports IT companies. The eBaby service allows citizens to complete a comprehensive online registration of a newborn child, while a simplified procedure for applying for a business registration and obtaining a license greatly facilitates access to public services. The platform also provides features of interaction with the authorities, including openness (monitoring of decisions and budget expenditures) and the possibility of civic participation through electronic petitions, consultations and polls.

The main achievements of the Diia platform include a high level of service speed, for example, registration of individual entrepreneurs through the Diia takes only 10 minutes, this significantly reduces the burden on government agencies. The platform promotes transparency through the use of blockchain technology for data protection, which ensures trust among users. Its popularity among the population, with more than 20 million users of the mobile application at the beginning of 2025, confirms the platform's effectiveness and demand. The rapid response to crisis situations, including in the context of the full-scale war in 2022, allowed Ukrainians to receive assistance for internally displaced persons, file claims for destroyed property, and receive compensation and benefits.

The platform's advantages also include the convenience of accessing public services from anywhere, without the need to visit institutions, integration with other systems such as the State Register of Civil Status Acts and the Unified State Register of Legal Entities, and the use of innovative

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ISBN 978-9916-9320-3-2 (pdf)

technologies, including cloud computing, blockchain and artificial intelligence. Automation of processes significantly reduces opportunities for corruption, making the platform more efficient and reliable.

However, in addition to the obvious advantages, there are also certain challenges, such as the low level of digital literacy among certain groups of the population, the need to modernize infrastructure in rural areas, as well as the threat of cyberattacks and the need to ensure the security of personal data (Storozhenko, 2022).

The further development of the Diia platform involves expanding its functionality, integrating new services, and strengthening international cooperation to share experience and technologies. The Diia platform is a vivid example of successful digitalization of public services, demonstrating the potential of innovative technologies to enhance interaction between the state and citizens. It has become a symbol of Ukraine's progress towards transparent, efficient and accessible governance.

However, the process of digitalization, in particular through the Diia platform, faces certain difficulties that are typical of the general challenges inherent in digital transformation, namely:

– low level of digital literacy of the population;
– insufficient infrastructure in rural areas;
– cybersecurity threat - the need to protect personal data;
– resistance to change among both citizens and civil servants.

The main barriers to digitalization include technical, organisational, ethical and legal aspects. Technical barriers include outdated information systems that do not meet modern requirements. Organisational obstacles arise from resistance to change among staff and insufficient digital literacy. Ethical and legal issues are caused by the need to protect personal data and ensure cybersecurity. It is important to develop a comprehensive strategic policy that includes training, infrastructure upgrades, and enhanced cyber defences to effectively overcome these challenges,

The main stages of digitalization of public administration are shown in Figure 1.2.

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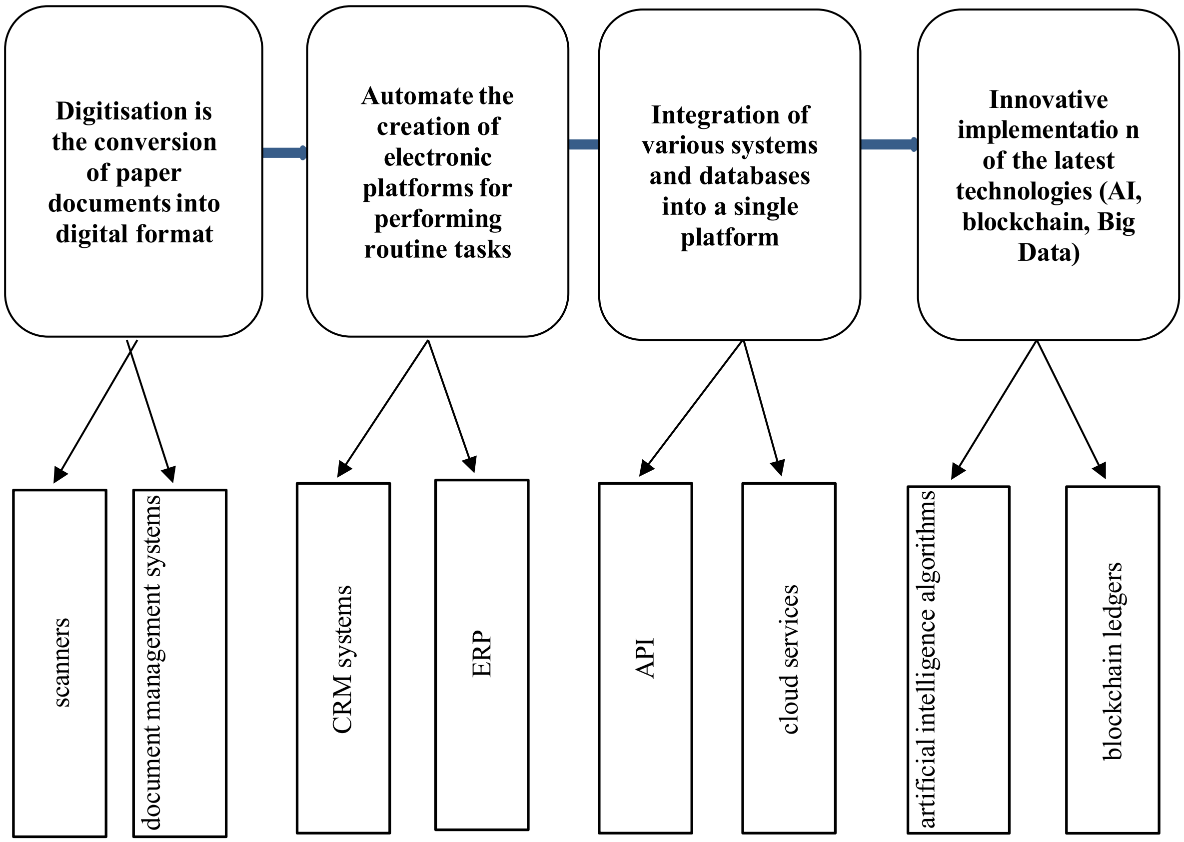

Figure 1.2. Key stages of public administration digitalization
Source: developed by the author

It is advisable to take into account a number of criteria, including: efficiency (speed of service delivery), transparency (access of citizens to information and processes), trust (level of public satisfaction), cost-effectiveness (reduction of administrative costs) and inclusiveness (accessibility of services for different social groups) to ensure the transparency and efficiency of digital transformation.

The effectiveness of digital technology implementation can also be assessed by the following criteria: accessibility of services (the ability to receive services online regardless of place of residence or technical conditions), productivity (speed and efficiency of administrative processes), quality of service (citizen satisfaction and ease of use of services), citizen engagement (active participation in processes through electronic platforms such as petitions, surveys, etc.), data security (ensuring cybersecurity and privacy of individuals).

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ISBN 978-9916-9320-3-2 (pdf)

The proposed criteria can serve as a basis for monitoring, analysis and further improvement of digital initiatives. Table 1.1 summarizes the main indicators of digitalization effectiveness.

Table 1.1. Key performance indicators for digitalization

Indicator	Metrics	Performance evaluation
Availability of services	Share of the population using online services	Growth of 15% annually
Saving resources	Reduced administrative costs	From 10% to 25% of the total
Speed of service	Average request processing time	Change by 2-3 times
Level of engagement	Number of electronic petitions/surveys	Increasing civic engagement
Transparency	User evaluation based on open data	Growth of trust

Source: developed by the author

Effective digitalization of public administration requires modernization of the infrastructure, including the creation of unified information platforms, and raising the level of digital literacy among public personnel and citizens through training programmes. Important elements include the integration of innovative technologies such as blockchain, artificial intelligence and the Internet of Things, the development of standards to unify approaches to performance measurement, and the development of public-private partnerships, which involve active cooperation with business and civil society (Bondarchuk & Dubrova, 2023).

Digitalization is based on the use of digital technologies for processing, storing and transmitting information, which significantly changes society, economy and culture by transforming them into digital form. The widespread adoption of these technologies has led to significant changes in various spheres of life, including public administration, where electronic forms of interaction between participants in social relations are developing. This, in turn, has contributed to the formation of e-government in developed countries.

The UN website is evidence of the global spread of digital technologies. According to the latest UN data, in 2024, Denmark, Estonia, and Singapore became the leaders in terms of e-government development (United Nations, 2025).

Ukraine has made significant progress, moving up 16 positions since 2022 to 30th place. In addition, Ukraine has improved its E-Participation Index ranking, rising to 56th position since 2022 (Forbes Ukraine, 2024). Ukraine was also ranked fifth in the world in terms of digital public services.

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ISBN 978-9916-9320-3-2 (pdf)

These achievements reflect the successful digital transformation and effective implementation of electronic services in Ukraine (Interfax-Ukraine, 2024).

Digitalization brings significant benefits, but it also raises a number of challenges that have social, economic and governance implications. One of the main challenges is the inequality between those who have access to digital technologies and digital literacy skills and those who do not. This can lead to social barriers, economic inequality and limited access to information and services. For example, the efficient delivery of administrative services depends on the proper functioning of digital platforms such as Diia, which require access to high-speed internet and appropriate technical equipment. In Estonia, 99 per cent of public services are available online, indicating a high level of digitalization, but modern devices and appropriate skills are required to fully use such services.

The growth of digital data requires effective protection against cyber threats. The issues of digital infrastructure security, protection of personal data and prevention of unauthorized access require the development of government policies and relevant legislation. For example, the European Union has implemented a number of initiatives to standardize electronic identification and trust services (Syrotin, 2023).

The rapid development of digital technologies is outpacing the pace of regulatory development, which requires the creation of new rules and procedures for the introduction and use of digital innovations. In Germany, coordinating bodies have been established to promote the active development of e-government.

Despite these challenges, digitalization is significantly increasing the efficiency of public administration. The UK, for example, has developed an e- government system that provides secure access to public services via the Internet, mobile communications and digital television. The positive impact of digitalization of administrative services is estimated to be 20-50 times higher than traditional methods.

In Estonia, the reduction of bureaucracy through the introduction of digital technologies has resulted in 800 years of working time being saved. Ukraine is also actively moving towards digitalization. Following the implementation of the Concept for the Development of the Digital Economy for 2018-2020, the country has made significant progress in digital transformation. As of 2025, a number of important achievements can be noted:

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Firstly, an increase in positions in international rankings: Ukraine has moved from 102nd to 5th place in the UN Online Service Index, which assesses the development of online services in 193 countries (United Nations, 2025).

Secondly, the number of users of the Diia platform has grown to over 21.8 million. The app provides access to 28 digital documents and more than 30 services, including new services such as digital passports, simplified business registration and recognition of EU COVID certificates.

The government's plans to invest in the restoration of telecommunications infrastructure, which envisage investments of UAH 17.8 billion to provide 95% of the population with access to mobile Internet at a speed of at least 2 Mbps by the end of 2025.

Launch of a special legal regime called the Diia City, which brings together more than 1450 companies and 94,000 specialists to promote the development of technology business in Ukraine.

The Diia.Osvita platform offers more than 57 new educational products aimed at improving citizens' digital skills.

These achievements demonstrate Ukraine's significant progress in developing its digital economy and integrating the latest technologies into the everyday life of its citizens.

In order to achieve effective digitalization in Ukraine, it is important to develop a national strategy that includes: the development of Internet infrastructure with access for all citizens, increasing digital literacy of the population and ensuring the protection of citizens' rights in the digital space (Syrotin, 2023).

Thus, digitalization is a powerful tool for modernizing public administration, but its success depends on the state's ability to effectively cope with challenges and find a balance between technological progress and social justice.

Let us consider the prospects for the development of e-government. The future of e-government is closely linked to the development of artificial intelligence, blockchain technologies and big data. Their integration will allow to: improve the forecasting of management decisions, increase the level of personalisation of administrative services, and ensure maximum transparency and security of data. The advantages and disadvantages of digitalization technologies for management processes are compared in Table 1.2.

https://doi.org/10.36690/CIDI-EME
ISBN 978-9916-9320-3-2 (pdf)

Table 1.2. Comparison of key digital technologies in public administration

Technology	Features	Advantages	Challenges
Artificial intelligence (AI)	Data analysis, automation of routine tasks	Forecasting, efficiency	High cost, ethical issues
Blockchain	Data storage and verification	Transparency and security	Implementation costs
Big data	Processing large volume of data	Understanding the needs of citizens, strategic planning	Data privacy
Cloud computing	Data storage, service availability	Flexibility, cost reduction	Cybersecurity risks

Source: developed by the author

E-government is a key element of the digitalization of administrative management. It not only helps to increase the efficiency and transparency of administrative processes, but also becomes a catalyst for democratic change. Successful implementation requires a comprehensive strategy that includes infrastructure development, digital literacy and cybersecurity. Digitalization is the basis for modernizing administrative governance, which ensures transparency, efficiency and trust in government. Successful integration of digital technologies requires a comprehensive approach, an effective strategy, and consideration of the specific characteristics of each country. Overcoming barriers and actively implementing innovations contribute to the sustainable development of society and the state.

2. Use of social media and other digital channels for management communication. Digitalization has transformed approaches to management communication, where social media and other digital channels have become important tools for effective interaction between managers, employees and external stakeholders. Thanks to the development of these technologies, management communication has gone beyond the traditional process of transferring information between levels of an organization to include interactive platforms that simplify data exchange and create new opportunities for influencing the audience. The use of these technologies makes it possible to ensure efficiency, transparency and interactivity in the interaction between managers, employees and external stakeholders.

Social media, in particular platforms such as Facebook, LinkedIn, Twitter, Instagram, are leading digital communication channels that provide accessibility, interactivity and a wide reach to the target audience. They

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ISBN 978-9916-9320-3-2 (pdf)

function as effective channels for information exchange, enabling connections between managers, employees, partners and the public. Within the framework of these communication tools, managers can not only deliver strategic messages, but also shape the corporate image, maintain the organization's reputation, establish professional connections and promote the organization's goals (Razumei & Razumei, 2020).

The main functions of social media in management communication are:

1. Informing - social media provides a fast and effective way to disseminate news about the organization's activities and changes in its strategy, for example, by publishing updates on the company's Facebook or LinkedIn pages.

2. Feedback - platforms provide an opportunity to receive feedback from employees, customers and partners in real time, for example, through polls on Instagram Stories or comments under posts.

3. Reputation management - maintaining official accounts on social media allows you to create a positive image of your organization and respond quickly to crisis situations, for example, by publishing official statements or apologies on Twitter.

4. Supporting corporate culture - social media serves as a tool for developing corporate values by publishing employee achievements and organizing online events, as is done, for example, through LinkedIn.

5. Expanding the audience - social media allows you to attract new partners, customers and talent by presenting the organization in the public arena, which is actively used through Instagram or TikTok to promote among young audiences.

The key advantages of social media for managerial communication include their speed and accessibility, which ensure prompt exchange of information. Another important feature is interactivity, which allows for two-way communication with the audience. The scale of coverage is another significant advantage, as social media makes it possible to work with different groups, both internal and external. In addition, the cost-effectiveness of these platforms, including the possibility of using them for free or at low cost, makes them beneficial for organizations.

The main challenges of using social media are a number of factors related to security, content management and information processes. One of the key issues is cybersecurity, as there are risks of personal data leakage or account hacking. Another important issue is the misuse of social platforms, when

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ISBN 978-9916-9320-3-2 (pdf)

inappropriate content can negatively affect the image of an organization or individual. Another significant challenge is information overload, which arises from a large amount of content that can distract users. In addition, there is a dependence on social media algorithms, as the visibility of posts and content is largely determined by platform settings.

Let's compare the advantages and disadvantages of popular social networks in Table 1.3.

Table 1.3 Comparison of advantages and disadvantages of popular social networks in management communication

Social network	Advantages.	Disadvantages.	Main audience
Facebook	- A wide audience. - Analytics tools. - Groups for internal communications.	- High competition for attention. - Difficulty of organic coverage.	Adult audience (25-55 years old).
LinkedIn	- Professional network. - Formation of a corporate image.	- Narrow specialisation. - Limited interactivity.	Professionals, companies, B2B segment.
Twitter	- The speed of information dissemination. - Openness of the platform.	- Limits on the number of characters. - Tailor to specific audiences.	Journalists, public figures, young people.
Instagram	- Visually appealing content. - Ample opportunities for advertising.	- High dependence on the visual component. - Focus on B2C, less effective in B2B.	Young people, consumers of products/services.
TikTok	- Popularity among young people. - Creative content.	- Limited audience for B2B. - High speed of trend	Generation Z (13-25 years old).
Telegram	- Security. - Creation of corporate chats and channels.	- - Lack of algorithmic support.	Different age groups, with a focus on young people.
YouTube	- Long-term impact of video content. - Tools for analytics.	- - High production costs	All categories

Source: developed by the author

In addition to social media, other digital tools are actively used for management communication, including messengers such as WhatsApp, Telegram, and Slack. These platforms provide a fast and convenient exchange of information, which is important for effective management. Messengers allow you to create groups, channels, organize discussions and share files in

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real time, which is essential for a flexible management process. They have a number of functional capabilities, such as instant information exchange, group work organization, file sharing, integration with other tools, security and privacy, and automation capabilities. These tools play an important role in ensuring the efficiency and effectiveness of management communication in organizations (Sinyakov & Hrynchak, 2023).

Consider the functionality of messengers in management communication.

1. *Prompt information exchange.* Messengers provide instant communication between team members, managers, and subordinates, which is especially useful in crisis or urgent situations. For example, notifications about changes in the meeting schedule or urgent instructions.

2. *Organization of group work.* Working groups allow you to coordinate work between departments or divisions of an organization. An example: creating a group to discuss a specific project with participants from different departments.

3. *File sharing.* Integrated functions for sharing files (documents, presentations, reports) greatly simplify access to information. Example: sending out an updated version of an organization's development strategy.

4. *Integration with external tools.* Some messengers, such as Slack, support integration with other digital platforms, such as Google Drive, Trello, and Jira, which extends their functionality. Example: automatically receiving notifications from a project management system in a group chat.

5. *Security and confidentiality.* Thanks to encryption (end-to-end encryption), messengers provide a high level of information protection. Example: Telegram or WhatsApp are best for discussing confidential topics.

6. *Automation capabilities.* Bots and automation tools help you send out effective emails, answer questions, and send reminders. Example: A Slack bot that reminds you of deadlines on a daily basis.

Messengers have a number of advantages, including the speed of information exchange, accessibility from different devices (smartphones, tablets, PCs), flexibility that allows them to adapt to different communication needs, and cost-effectiveness, as most platforms provide basic functions for free. In addition, these tools provide interactivity, allowing for real-time discussions (Sinyakov & Hrynchak, 2023).

However, there are also some disadvantages. Among them are information overload, when a large number of messages can make work

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difficult, and a low level of structuring, which makes it difficult to organize information in large groups. Another important factor is security risks, as despite encryption, some organisations may face potential information leaks. In addition, the lack of a clear line between work and personal life due to constant notifications can create additional difficulties for employees. Comparative table of messengers for management communication is given below (Table 1.4).

Table 1.4 Comparative table of messengers for management communication

Messenger	Advantages	Disadvantages	Optimal use
WhatsApp	- Easy to use. - Popularity among employees.	- Limited functionality for large teams. - Less effective in large organisations.	Small and medium-sized organisations, fast information exchange.
Telegram	- Channels for broad information. - Bots for process automation.	- There is no built-in integration with other platforms.	Mailings, automation, information storage.
Slack	- Integration with other tools. - Clear structuring of channels.	- The cost of premium features. Less convenient for users without technical experience.	Large teams, project management, integration with tools (Trello, Google Drive).

Source: developed by the author

Email remains an important and effective tool for formal communication in management practice. It is one of the most versatile channels for business correspondence, convenient for sharing important documents and communicating with partners, clients and internal teams.

Email provides a formal communication format that allows you to keep a history of communications by keeping all emails in an organized manner. It allows you to efficiently exchange documents in various formats and send mass mailings to inform a large number of people. In addition, email supports business etiquette by using official templates and signatures (Razumei & Razumei, 2020).

Email has a number of important functions in management communication. It is a standard tool for official business correspondence, including the exchange of important documents such as official letters, contracts, invitations or reports. In addition, email provides a history of communications, which allows you to systematize your correspondence and

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track previous discussions and decisions. This feature is especially important for monitoring task completion and decision- making.

Document sharing is another essential feature of email, as it supports the ability to attach files of various formats, such as documents, spreadsheets and presentations. This makes it an effective tool for sending financial reports, presentations or other important materials. Additionally, email allows for mass mailings, which makes it possible to inform a large number of people at the same time. It is a convenient solution for distributing corporate newsletters to employees or partners.

Another important function is to maintain formality and etiquette in communications, as email allows you to use official templates and signatures, which helps to maintain professionalism in business communication.

The main advantages of email include its versatility, accessibility across devices and compatibility with many platforms, as well as its organization through sorting, filtering and folder creation. Security is also an important advantage, thanks to the ability to encrypt emails and the use of corporate servers. However, email also has a number of disadvantages. One of them is information overload, when a large number of emails can lead to the loss of important information. In addition, the lack of interactivity slows down the discussion of urgent issues, and cybersecurity risks, such as phishing and viruses, pose threats to confidential information. Another problem is the lack of personalization of communication, which requires the use of templates or additional automation tools, and the difficulty of tracking tasks that are better controlled through specialized applications.

To ensure that email is used effectively, there are a few guidelines to follow. Firstly, it is important to ensure that the format of the email is clear, in particular by using clear topics and structured paragraphs that make the information easier to understand. Secondly, in order to maintain the company's image, it is advisable to use corporate email clients with domain-based email services, for example, through addresses such as name@company.com.

Automation of processes is also an important practice; using mass emailing tools such as Mailchimp or Constant Contact, as well as using email templates, greatly increases the efficiency of communication. In addition, organizing your emails by creating folders and filters to sort them by project, priority, or sender helps keep your correspondence organized.

The last but not least aspect is ensuring the security of correspondence:

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for this purpose, two-factor authentication and encryption of emails must be used, which guarantees protection against unauthorized access.

Let's look at an example of using email in management communication Situation: The head of the company is planning to update the remote work policy.

Step 1: Send an email to employees explaining the changes and attaching the document for review.

Step 2: Set a deadline for providing feedback.

Step 3: Organize the responses you receive using mailing labels.

The advantages and disadvantages of email for management communication are shown in Table 1.5.

Table 1.5 Comparing the advantages and disadvantages of email for management communication

Advantages	Disadvantages
Versatility and accessibility	Slowness in case of urgent issues
Saving the history of correspondence	Information overload
Ability to attach documents	Cybersecurity risks
Formality and professional style	Lack of interactivity
Support for mass email campaigns	Limited efficiency in project management

Source: developed by the author

Email remains an effective tool for performing formal and structured tasks, ensuring long-term preservation of correspondence. However, its potential is greatly enhanced when combined with other digital communication channels.

Web platforms and websites also play an important role in providing access to information resources and interactive services. These tools help to increase transparency, interactivity and accessibility of information, which allows organizations to effectively provide services, inform about their activities and interact with the public, which is an important aspect for internal and external stakeholders (Storozhenko, 2022).

One of the main functions of web-based platforms is to provide easy access to key information related to an organization. This includes the mission, goals, contact details, as well as news and reports that are important to stakeholders such as partners, customers and investors. Through this access,

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organizations can keep stakeholders informed and ensure that information published on official resources is always up-to-date. For example, government agencies use their websites to publish legislation, new regulations and reports, which helps citizens and businesses to obtain the information they need directly from official sources.

Interactivity is an important feature of web platforms. Through feedback tools such as forms, online consultations, chat bots, or other interactive elements, organizations can interact directly with users, giving them the opportunity to ask questions, get advice, or leave feedback in real time. These tools increase the level of communication by providing effective interaction with the audience, which is an important aspect for organizations focused on a high level of customer service. For example, chatbots on local government websites allow citizens to get instant answers to frequently asked questions or other requests.

Web-based platforms also provide an opportunity for organizations to efficiently deliver electronic services. This includes filing applications, paying bills, registering documents or other administrative services. With the help of web platforms, citizens and businesses can receive services from the comfort of their homes or offices, which greatly increases convenience and saves time. A prime example is online platforms such as the Diia portal in Ukraine, which provides access to numerous government services such as business registration, paperwork or obtaining various certificates.

Websites are important reputation management tools for organizations. They allow organizations to create and maintain a positive image through the publication of successful cases, customer reviews, social initiatives, environmental projects, or charity events. This allows organizations to create an open and transparent image, increasing brand trust among consumers and other stakeholders. For example, companies can publish customer success stories or the results of their environmental initiatives on their websites, which helps to improve their image and public relations.

Another important aspect is the use of web-based platforms for learning and professional development. Websites and platforms can be used to organize online courses, trainings or provide access to document libraries, allowing employees of organizations to improve their qualifications and professional skills. For example, companies can create corporate learning portals where employees can take courses in areas ranging from soft skills development to specialized professional topics.

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In addition, monitoring and analytics play an important role. Web platforms provide access to web analytics tools, such as Google Analytics or Hotjar, that allow organizations to track website traffic, user behavior and content performance. These tools help to assess how users interact with information on the website and measure the effectiveness of marketing campaigns. For example, website traffic data can indicate the effectiveness of promotions or content changes, which allows you to quickly adjust your communication and marketing strategy (Blinova, 2021).

The types of web-based platforms for management communication are shown in Table 1.6.

Table 1.6 Types of web platforms for management communication

Platform type	Main tasks	Example.
Corporate website	Information about the organization, access to contacts, PR activities.	The official website of a company or institution.
Service portals	Providing administrative or commercial services.	"Diia, PayPal, and online registration portals.
Learning platforms	Organization of courses, trainings, and knowledge testing.	Cour

Source: developed by the author

Video conferencing has become an important tool for management communication in today's digital environment, driven by the growing popularity of remote work. Video communication platforms, such as Zoom and Microsoft Teams, provide an opportunity to hold online meetings, presentations, trainings and discussions in real time. These tools facilitate effective communication and interaction between participants, regardless of their geographical location, which is especially important for organisations with global teams or when issues need to be resolved quickly.

Video conferencing plays a key role in modern management communication practices, especially in the context of digitalization and the growing popularity of remote work. Platforms such as Zoom and Microsoft Teams provide the ability to effectively organize remote meetings, enabling organisations to maintain productivity even when participants are in different geographical locations. This is especially important for international and cross-regional teams, which often need to coordinate their activities without being physically present.

Video conferencing features also include information visualisation, which greatly improves the process of communicating and discussing complex ideas. Screen sharing, presentations and documents allow meeting participants to have a clear view of the materials being discussed, which greatly improves the quality of communication and allows executives to explain strategic issues, financial reports or new projects in a convenient way. This is especially useful in the context of reporting meetings, investor presentations, or when discussing important management decisions.

In addition, videoconferencing is used to organize trainings, seminars and webinars to promote the continuous professional development of employees. These platforms allow training to be delivered from anywhere in the world, giving employees access to a variety of courses and information resources. In many cases, this replaces traditional forms of training, including external lecturers, which saves time and resources for the organisation.

Video conferencing platforms also enhance team collaboration by providing tools for collaborative document editing, polling, and interactive white boarding. This allows meeting participants to work on joint projects in real time, discussing and making adjustments without the need to be physically present. Such features are especially important for brainstorming, strategy planning, developing new products or services, and solving urgent operational issues.

In addition, video conferencing has a meeting recording feature that allows you to save important sessions for later review. This is useful for those participants who were unable to attend the meeting, or when it is necessary to review the discussion to clarify certain details or decisions made. Saving recordings can also be an important tool for analyzing the effectiveness of communication and making decisions in the future.

Thus, videoconferencing is a powerful tool for supporting effective and interactive management communication, contributing to both improving internal information exchange and developing external communications with partners, customers and other stakeholders.

Video conferencing platforms offer numerous benefits for management communication. One of the main advantages is their accessibility, as they support a variety of devices, such as personal computers, tablets and smartphones, which ensures their versatility and convenience for users. In addition, the use of such platforms can significantly reduce the costs associated with transport, accommodation and physical meetings, making them cost-effective. Video conferencing is also highly efficient, as it allows you to quickly organize meetings when needed, without significant time or

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financial costs. Another important advantage is flexibility, as video conferencing platforms allow you to set up different meeting formats: individual, group or multi-user, to meet the requirements of a particular situation. In addition, video conferencing is highly interactive, as it includes polling, chat and response tools that encourage active participation and engagement in discussions.

However, there are several disadvantages to using video conferencing. One of the main problems is the dependence on a stable Internet connection, as poor connection quality can significantly reduce the effectiveness of the meeting and create technical difficulties. Participants may also face problems with sound or video setup, which can lead to delays or misunderstandings during discussions. Another important aspect is the lack of face-to-face interaction: despite visual communication, non-verbal communication opportunities are limited compared to face-to-face meetings, which can affect the quality of mutual understanding. Prolonged use of video conferencing can cause "digital fatigue", which is expressed in reduced concentration and fatigue of participants. In addition, there is a risk of data security: the use of unsecured platforms can create threats to confidential information, which is especially important for organizations that work with sensitive data.

In the context of management communication, an important aspect is the choice of a platform for organizing video conferencing and team collaboration. Zoom and Microsoft Teams are two of the most popular tools for this purpose, and a comparison of the two platforms allows us to identify the key benefits and features of each. Table 7 below shows the main features of these platforms, allowing you to evaluate their functionality, usability and integration with other tools, which is important for choosing the best solution depending on the needs of the organization.

Preparing for video conferencing requires a thorough check of the technical equipment, including the camera, microphone, and stability of the Internet connection. It is also important to set the agenda in advance by clearly articulating the objectives of the meeting and sharing them with the participants. Appointing a moderator is essential to ensure that the meeting stays on track and that time is managed effectively. Interactive tools such as polls, chat or reactions can be used to facilitate more active participation in the discussion. In addition, it is advisable to keep records of important meetings for further analysis or to pass on information to those who could not attend.

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Table 1.7 Comparison of Zoom and Microsoft Teams

Characteristics	Zoom	Microsoft Teams
Main purpose	Video conferences, webinars	Video conferencing, integration with Office 365 corporate tools
Number of participants	Up to 100 (free of charge), up to 1000 (with extended tariffs)	Up to 300 (free of charge), up to 10,000 (with a corporate rate)
Features.	Meeting recording, chat, screen sharing	Collaborative file editing, integration with Microsoft Office, chat
Ease of use	Intuitive interface, easy setup	Requires basic knowledge of the Microsoft ecosystem
Security.	Data encryption, password protection	Enterprise-level security, integration with Active Directory
Target audience	Education, small and medium-sized enterprises	Corporations, large teams

Source: developed by the author

Video conferencing, including platforms such as Zoom and Microsoft Teams, are essential tools for effective management in today's digital environment, as they enable continuous communication, idea sharing and decision making, despite the geographical distance between participants. However, to maximise the effectiveness of such platforms, it is important to develop a digital communication strategy that includes a clear definition of goals and expected results. An important component is to train employees in the use of various digital communication tools, including social media and messengers. Ensuring cybersecurity is also an important aspect, so it is necessary to implement modern data protection protocols. Regular monitoring of the effectiveness of digital channels allows for timely assessment and adjustment of the use of platforms. Integration of various tools into a single system helps to ensure their ease of use for end users. Effective use of social media is also important, as it promotes interactivity, rapid information exchange and increased transparency of communication. However, a thoughtful and responsible approach is required to ensure security and maximize the impact of digital channels.

3. Shaping digital culture in public administration. Culture plays an important role in shaping public participation in public administration processes, which directly affects the effectiveness of policy development and implementation at various levels of administration. One of the key tasks of the authorities is the effective use of combinations of management tools capable of navigating complex and often conflicting management

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processes. This requires a deep understanding of cultural biases and mechanisms that facilitate informed and effective decision-making by policy analysts and managers. In today's environment, it is of particular importance to develop a new managerial culture that meets the requirements of public management and digital transformation. Public administration employees must demonstrate a high level of administrative service culture, aiming to build a service state. This approach helps to strengthen public trust, improve the image of organizations, develop business ethics and ensure effective communication with all stakeholders (Atamanova & Kotysh, 2022).

State institutions, whose activities are regulated by law, should form a unique cultural environment inherent in public institutions. Unlike the private sector, which is focused on profit and market competition, public administration is aimed at meeting public needs and ensuring sustainable development.

In the context of globalisation and full-scale war, management culture must be transformed to adapt to new challenges. Managers must be able to make an informed decision on their own, respond effectively to crisis situations and implement complex practical tasks. This requires not only professional competences, but also the development of behavioural, psychological and ethical skills that are oriented towards the needs of citizens and the principles of service management.

Building a modern managerial culture is the basis for improving the efficiency of public administration, strengthening public trust in state institutions, and achieving sustainable socio-economic development. The digitalization of public administration is not only a matter of implementing technology, but also of transforming organisational culture. Digital culture provides a new approach to work, communication, decision-making and interaction with citizens. The formation of a digital culture in the public sector is a prerequisite for the effective implementation of digital strategies, ensuring transparency, efficiency and compliance.

Digital culture is a system of values, beliefs and behavioural norms aimed at using digital technologies to achieve the strategic goals of an organisation. In the context of public administration, digital culture covers such important aspects as digital thinking, which is manifested in the readiness of managers and employees to perceive technological change as a necessity for the development of the organisation. Innovation is expressed in the introduction of new approaches to solving problems using technology.

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Flexibility is defined by the ability to quickly adapt to changes in the environment, and transparency is the use of digital tools for open access to data and reporting. Finally, citizen-centricity implies a focus on the needs of citizens through digital services.

The importance of digital culture in public administration lies in the optimisation of internal processes. It facilitates the automation of routine tasks, which increases efficiency, and ensures transparency through the use of open data and electronic platforms that hold public authorities accountable to citizens. A digital culture also contributes to improved interaction, as the use of digital communication channels facilitates the exchange of messages between departments and external stakeholders. It increases public trust in government as digitalization helps to eliminate bureaucratic barriers.

The formation of a digital culture in public administration depends on several key factors (Table 8), including leadership, which includes active support for digital change by the organizations' leaders, as well as their example in developing the digital competence of employees.

Table 1.8 Factors of digital culture formation in public administration

Factor	Role in shaping digital culture	Example
Leadership	Prioritising digitalisation and employee engagement	Organising seminars on digital management
Training	Developing digital competencies among employees	Conducting courses using the CRM system
Infrastructure	Providing technical means of access to digital tools	Installation of an electronic document management system
Motivation	A desire to implement digital solutions	Paying bonuses for digitalisation proposals
Regulatory and legal support	Legitimising digital processes	Adoption of laws on electronic document management

Source: developed by the author

Ongoing staff training through workshops, seminars and courses on digital technologies is also important. An infrastructure that provides access to modern technologies and cybersecurity tools is a prerequisite for implementing a digital culture. Motivating employees to successfully use digital solutions through a system of incentives and supporting the legal and regulatory framework that governs digitalisation processes also contribute to the development of a digital culture.

The formation of digital culture goes through the following stages:

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1. *Diagnosing the digital maturity of the organisation.* Analysing the current state of digitalization. Identify weaknesses in the use of digital technologies.

2. *Development of a digital culture strategy.* Formation, vision and goals in the field of digitalization. Develop an action plan involving all levels of the organisation.

3. *Staff training and development.* Organisation of trainings using digital technologies. Raising awareness of the importance of digital security.

4. *Implementation of digital tools.* Launch of an electronic document management system, online communication platform, CRM system. Integration of technologies such as artificial intelligence, Big Data, blockchain.

5. *Monitoring and evaluation.* Tracking progress in the implementation of digital technologies. Analyzing the effectiveness of changes and adjusting the plan (Bondarchuk & Dubrova, 2023).

Conclusions. The development of a digital culture in public administration faces several significant challenges. One of the main ones is resistance to change, when employees may be reluctant to adopt new technologies due to fear of the unknown or lack of motivation. Another important factor is the lack of competencies, including low levels of digital literacy among employees of public institutions, which makes it difficult to effectively implement digital tools. Infrastructure constraints, including the lack of modern hardware, software, and access to high- speed Internet, pose significant challenges to the digitalization process. Financial barriers also remain an obstacle to the implementation of large-scale digital projects due to insufficient funding. In addition, cybersecurity is one of the biggest threats, as there is a risk of data leakage, hacking and unauthorized access to confidential information.

Examples of successful digital culture can be seen in different countries that have become models of digital transformation in public administration. In Ukraine, one of the most striking examples is the Diia platform, which combines a number of public services in a single digital space. This initiative greatly facilitates access to administrative services for citizens, ensuring high speed of their provision and transparency of processes. The Diia platform includes not only administrative services, but also digital documents, which allows citizens to carry out paperless transactions, reducing the time spent on obtaining the necessary services. In addition, this creation of a single digital

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environment for public services has improved interaction between public authorities and citizens, ensuring greater efficiency of management processes. The introduction of the Diia platform was an important step towards the digital transformation of the public sector, which in turn strengthened public trust in public authorities among citizens.

Estonia is another outstanding example of a country that has successfully implemented a digital culture through its e-government system. For more than two decades, Estonia has been a leader in digital technology, introducing innovative approaches to governance that allow citizens to receive the services they need online. The Estonian e-government system includes electronic services for company registration, tax returns, voting in elections, etc. Thanks to such measures, the country has achieved a high level of transparency, reduced bureaucracy and increased trust in the authorities. At the same time, the Estonian model of digital governance has reduced the cost of processing administrative cases and increased the level of citizen participation in public administration.

On the other hand, the European Union's Digital Europe programme has become an important tool in the development of digital skills, infrastructure and innovative projects among EU member states. The programme includes initiatives to develop digital infrastructure, invest in digital skills training for citizens, and support start-ups and technological innovation. This allows EU member states to respond effectively to the challenges of digitalization, promoting the introduction of the latest technologies in public administration and ensuring the sustainable development of digital solutions in the EU. Thanks to such initiatives, EU countries have achieved good results in providing access to digital services and have created favourable conditions for the integration of new technologies into public administration.

Building a digital culture in public administration is an important step in the context of the digital transformation of the public sector. Its successful implementation requires active leadership, ongoing staff training, infrastructure development, and overcoming challenges such as resistance to change and financial constraints. Investing in the development of digital culture has the potential to significantly increase the efficiency of management processes, promote transparency in the work of government agencies and strengthen public trust in public authorities.

Digital technologies have become an important tool for transforming public life, covering all areas of governance, including economic and public

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administration. The formation of a digital culture in public administration is a prerequisite for the development of effective e-democracy, which ensures increased transparency, accountability of public authorities and interactivity with citizens.

Digital culture in public administration encompasses a system of values, norms and practices that focus on the use of digital technologies to achieve innovation, openness and accessibility of administrative processes. It forms the main basis for the formation of a service state, in which a citizen not only receives administrative services but also participates in decision-making.

In Ukraine, the introduction of digital technologies in public administration is significantly changing traditional approaches to administration based on paper documents and bureaucratic procedures. These changes create the conditions for the country's active integration into the global digital space and promote the development of e-democracy (Blinova, 2021).

The main characteristics of digital culture in governance are transparency and openness, which is achieved through the use of information and communication technologies that facilitate citizens' access to data on the activities of the authorities and their position on important public issues. The digitalization of management processes increases efficiency through automation, which reduces the influence of the human factor and increases the accuracy and speed of tasks. In addition, digital technologies can significantly improve the accessibility of public services, providing convenient access to them regardless of the geographical location of citizens, which helps to reduce bureaucratic barriers.

Automation of processes reduces opportunities for corrupt practices, as it reduces the frequency of direct contact between citizens and government officials. At the same time, the development of digital platforms promotes innovation in governance, including the introduction of advanced technologies such as artificial intelligence, blockchain and electronic identification, which open up new opportunities for improving public administration.

The formation of a digital culture in public administration is a prerequisite for effective digitalization and building e-democracy. Through the development of digital skills, infrastructure and innovation, public institutions can ensure transparency, accessibility and quality of services, strengthening public trust in government. The successful implementation of

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these changes requires a systematic approach, support from the leadership and the involvement of international experience (Sinyakov & Hrynchak, 2023).

The digitalization of public administration has great potential for further development. An important area of research is the development of integrated models of digital platforms, which involve the creation of common standards for data exchange between public and private entities. Expanding the functionality of digital platforms, in particular through the introduction of artificial intelligence tools and blockchain technologies, is also a promising area of research. Given the growing cyber threats, an important component is the development of monitoring and threat prevention systems to ensure cybersecurity.

Another important area is the adaptation of legislation to regulate the latest technologies used in public administration. At the same time, human capital development is a key element of digital transformation, including professional training of civil servants in digital governance, data analysis and cybersecurity. This will contribute to the successful implementation and support of innovative digital initiatives in the public sector.

The digitalization of public administration opens up new opportunities to improve efficiency and quality of services, while reducing costs and promoting transparency. However, to achieve sustainable results, a number of challenges need to be overcome: modernising technical infrastructure, improving legislation and attracting qualified personnel.

A comprehensive approach to addressing these challenges will be key to the success of digital transformation, making it a tool for progress and development of the information society, as well as ensuring public trust in government institutions.

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Section 1.2. The Effects of Digital Transformation in Female Leadership in Businesses

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Abstract. *Digital transformation is reshaping leadership by widening access to information, networks, and technology-enabled resources that can weaken traditional gender barriers in organizations. In this environment, women's leadership increasingly depends on digital literacy and digital capital, as well as the capacity to use social media, ICT tools, and artificial intelligence for strategic decision-making, visibility, and innovation. However, these advantages are not automatic, because structural bias, unequal access to finance and skills, and weak support ecosystems can preserve or even intensify gender imbalances in technology-intensive sectors and digital projects. This makes the topic especially relevant for understanding how inclusion-oriented digital strategies can improve organizational effectiveness and expand entrepreneurship opportunities, including in regional and rural contexts where digital channels can compensate for limited local infrastructure and markets. The study conceptually examines how AI, social media, and ICT affect women's leadership by enabling empowerment, reducing institutional barriers, and supporting inclusive organizational cultures and policies. Methodologically, it applies an integrative literature-based synthesis across digital transformation frameworks, women's leadership research, and cross-country empirical observations. The analysis structures evidence around enabling mechanisms, constraining factors, and leadership-related outcomes. The synthesis suggests that digital tools increase leadership visibility, expand professional networks, and support flexible work models that facilitate career progression and entrepreneurial action, particularly for women-led SMEs. Yet persistent underrepresentation in senior management and technology roles remains connected to structural barriers and insufficient inclusive policies. Overall, digital transformation strengthens women's leadership when combined with targeted capability development and policies that widen access to skills, finance, and digital infrastructure. Future research should test causal links between digital capital and AI adoption, compare sector-specific barriers, and evaluate which policy mixes most effectively increase women's representation and resilience.*

Keywords: *digital transformation; women's leadership; artificial intelligence; social media; ICT; digital literacy; digital capital; inclusive leadership; entrepreneurship; gender inequality; rural development; organizational culture.*

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1. Digital Transformation. Digital transformation has become the key driver of technology-focused innovations and processes in today's business world. Digital tools such as artificial intelligence, social media, and information and communication technologies are transforming many areas, from organizations' strategic decision-making processes to their operational activities, and require leaders to take on strategic and innovative roles (Areiqat, 2024, p.1087; McCall, 2024, p.1). This process creates a dynamic environment that presents both opportunities and challenges, particularly for women leaders. 2024, p.513). Women's acquisition of digital skills, development of leadership competencies and adoption of an inclusive leadership approach enable them to increase their influence in organizations and participate in innovative entrepreneurship activities (Thomas et al., 2024, p.513).

The representation of women leaders in the business world has historically been limited due to gender inequalities and structural barriers. Nevertheless, the flexible working models, social networking tools, and rapid access to information offered by digital technologies are creating new opportunities that support women's advancement to leadership positions (Alam et al., 2022, p.535; Hazudin et al., 2021, p.1). Digital leadership in regional and rural areas is critical to the development of women entrepreneurs, and social networks and workplace culture perceptions lead to different assessments of the digital transformation of SMEs led by women compared to those led by men (Hazudin et al., 2025, p.1; Sak et al., 2023, p.91).

However, in the digital transformation process, gender imbalance, structural biases, and inadequate support ecosystems emerge as significant barriers limiting the effective participation of women leaders (Syahputra & Shabira, 2025, p.1). Therefore, strengthening women's leadership is possible not only through the development of individual skills but also through the adoption of inclusive policies and leadership programs (Weber-Lewerenz & Vasiliu-Feltes, 2022, p.117; Wulandari & Ahmad, 2025, p.124).

The effects of digital transformation on women's leadership are critical to understanding the transformation process of the business world and the leadership potential of women. Research shows that the proper application of digital technologies enables women to become more visible and effective in leadership roles, while also increasing entrepreneurial opportunities and contributing to sustainable economic growth (Saranya & Chandrasekar, 2023, p.1; McCall, 2024, p.1; Busari et al., 2025, p.1). Therefore, understanding the

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potential of women's leadership in the business world through digital transformation and technology integration is essential for developing inclusive growth and equality strategies at both the corporate and societal levels (Al-Aali, Masmoudi & AlSaffar, 2024, p.18; Krchová & Höesová, 2021, p.524).

The study examines how artificial intelligence, social media, and information and communication technologies (ICT) empower women in leadership roles, reduce organizational barriers, and the impact of inclusive organizational cultures and policy implementation on enhancing gender equality. Furthermore, the contribution of factors such as digital skills, leadership development, financial access and digital capital to the business growth, economic empowerment and sustainable growth of women entrepreneurs is analyzed through regional and global examples. The study offers policy and practice implications for strengthening women's leadership, enhancing the success of digital transformation strategies, and ensuring inclusive economic contributions.

The rapid development of digital technologies is driving fundamental change in societies and economic activities across all sectors. In the transition from the information age to the smart society, transforming data into information has become the fundamental action of the digital age, and adapting to digital transformation has become essential for businesses to survive (Bozkurt et al., 2021, p.35). This process has a profound impact on businesses' operating models, processes, human resources, and customer relationships, increasing productivity and value creation (Ebert & Duarte, 2018, p.16; Tang, 2021, p.9).

Within the framework of Industry 4.0, the process initiated by artificial intelligence, robot technologies, 3D printers, and the Internet of Things has brought cyber-physical systems that integrate the physical and digital worlds into focus in areas such as production, services, logistics, and R&D (Türkel & Yeşilkuş, 2020, p.332; Yankın, 2019, p.1). Digital transformation offers a holistic transformation process that provides competitive advantage by transforming the organizational structure, business models, human resources and customer relations of businesses (Klein, 2020b, p.997; Aksoy, 2024, p.1).

Digital transformation is a multidimensional concept encompassing technology, process, and people-focused components. In the literature, the strategic, cultural, and organizational dimensions of digital transformation are supported by structured frameworks and roadmaps (Verina & Titko, 2019,

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p.1; Zaoui & Souissi, 2020, p.621; Vial, 2021, p.13; Ziyadin et al., 2019, p.408; Henriette et al., 2016, p.1). Digital transformation enables businesses, public institutions, and educational institutions to achieve evolutionary change through the strategic use of technology, the adoption of innovative business models, and data-driven process optimization (Lanzolla & Anderson, 2008, p.72; Gray & Rumpe, 2017, p.307; Tang, 2021, p.9).

To summarize the core logic of digital transformation in relation to women's leadership, Table 1.9 systematizes key dimensions of the transformation, the mechanisms through which they operate, and the typical opportunity and barrier patterns observed in practice.

Table 1.9. Digital transformation dimensions and implications for women's leadership

Dimension	What changes in organizations	Opportunities for women's leadership	Typical constraints that may persist	What management should ensure
Technological layer (AI, platforms, ICT)	Tools expand analytic capacity, communication speed, and automation	Higher visibility, faster access to information, stronger digital personal brand	Digital divide, biased algorithms, unequal access to advanced tools	Equal access to tools, responsible AI rules, role-based training
Process layer (workflows, HRM, operations)	Work becomes measurable, standardized, and traceable	Transparent performance signals, clearer promotion evidence, flexible work design	Informal networks still dominate decisions, unequal workload distribution	Fair metrics, transparent promotion criteria, workload monitoring
Strategic layer (business model, competitiveness)	Digital transformation drives new products, channels, and markets	New entrepreneurial entry points, especially for SMEs and rural contexts	Unequal access to finance and markets, weak support ecosystems	Inclusive innovation funding, market access programs, mentorship
Cultural and governance layer	Norms, leadership models, and inclusion policies shape adoption	Inclusive culture increases participation and retention	Structural bias, glass ceiling effects in tech-intensive roles	Inclusion targets, leadership programs, accountability mechanisms
Ecosystem layer (state, education, infrastructure)	External conditions shape feasibility and scale	Digital infrastructure enables growth beyond local markets	Infrastructure gaps, uneven regional education quality	Public-private partnerships, upskilling pipelines, rural connectivity

Note. Compiled by the author based on the subsection's synthesized arguments.

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As shown in Table 1.9, digital transformation influences women's leadership through multiple channels, but the net effect depends on whether organizations translate technology adoption into fair processes, inclusive governance, and accessible capability development.

Technological developments in the digital transformation process enable businesses to increase their digital maturity levels and develop innovative business models.. Businesses are striving to renew their business processes and increase their digital maturity levels with technologies such as social media, mobile applications, big data, cloud computing, and artificial intelligence (Asiltürk, 2021, p.647; Aksoy, 2024, p.1). Digital leadership plays a critical role in this transformation; integrating technology with business processes and the human factor to drive digital transformation is fundamental to successful implementation (Aksoy, 2024, p.1). Furthermore, a risk-taking culture is an important factor in the digital transformation process, encouraging innovation and providing a competitive advantage (Schwertner, 2017, p.388).

Digitalization has also become prominent in public and private administrations, and service delivery has become more efficient through sensors, advanced networks, wearable technologies, and GPS systems within the scope of the Internet of Things (Göçoğlu, 2020, p.615). The role of the state changes according to economic and social needs; digitalization and artificial intelligence stand out as the basic elements of the new development approach (Tamer & Övgün, 2020, p.775). For example, the Presidential Digital Transformation Office, established in Turkey in 2017, is shaping the future role of the state by monitoring digitalization and artificial intelligence applications (Tamer & Övgün, 2020, p.775). In this context, comprehensive strategies and roadmaps are required for the planning and implementation of digital transformation; otherwise, the process may create more disadvantages than advantages (Klein, 2020b, p.997; Bozkurt et al., 2021, p.35).

Digital transformation continues to make its mark in many areas. These areas encompass digital transformation and mobile applications, chatbots, job applications via QR codes, dashboard analyses, and AI-supported recruitment in the field of Human Resource Management (HRM) (Kırılmaz, 2020, p.188). These applications are critical for businesses to gain a competitive advantage (Kırılmaz, 2020, p.188). Digitalization in education and higher education is transforming learner and teacher profiles and institutional understanding. The transition from Education 1.0 to 4.0 and the digital solutions implemented

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during the pandemic are create examples of transformation in education (Koral Gümüşoğlu, 2017, p.30; Kocaman Karoğlu et al., 2020, p.147).

Digital entrepreneurship plays an important role in economic development, employment growth, and the spread of innovation. A study examining the status of digital entrepreneurs in Turkey and around the world in the regard of digital transformation predicts that the number of digital entrepreneurs will increase in the coming years (Eyel & Sağlam, 2021, p.7). From an economic perspective, digital and mobile ecosystems support economic development and increased prosperity; Information and Communication Technology (ICT) infrastructure investments strengthen economic growth through macroeconomic indicators and sectoral ecosystems (Pakdemirli, 2019, p.665). The effects of digitalization on companies, brands, and public administration increase the efficiency and competitiveness of businesses, and brands create value in global markets through digital transformation strategies (Altuntaş, 2018, p.1).

As a result, digital transformation is reshaping many areas such as society, the economy, businesses, education, and public administration, and is redefining production and service processes. For a successful digital transformation, comprehensive strategies, increasing digital maturity levels, digital leadership, and integrating the human factor are of critical importance. Businesses, government agencies, and educational institutions can gain a competitive advantage, encourage innovation, and support sustainable development by correctly understanding and implementing digital transformation. (Bozkurt vd., 2021, s.35; Klein, 2020a, s.24; Aksoy, 2024, s.1; Türkel & Yeşilkuş, 2020, s.332; Göçoğlu, 2020, s.615; Tamer & Övgün, 2020, s.775).

Overall, digital transformation should be understood as a systemic shift that combines technology adoption, process redesign, and capability development, rather than as the isolated introduction of new tools. Its managerial significance lies in the fact that it changes how organizations generate value, coordinate work, and make decisions, while also redefining the competencies required from leaders. In relation to women's leadership, digital transformation opens additional pathways to influence through visibility, network building, flexible work design, and data-informed decision-making, especially when social media and ICT platforms reduce dependence on traditional gatekeepers. At the same time, the same transformation can reproduce inequality if access to skills, finance, and

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enabling ecosystems remains uneven, or if organizational cultures and promotion practices remain biased. Therefore, the leadership outcomes of digital transformation depend on governance choices, including inclusive policies, targeted leadership development, and investments in digital infrastructure and literacy. This subsection supports the argument that digital transformation becomes an inclusion driver only when it is implemented with clear strategy, accountable leadership, and measurable actions that expand participation and opportunity.

2. Women's Leadership. It is well known that women's representation in leadership positions has historically been limited. Although studies conducted in the modern and postmodern periods show that there is no significant difference between female and male leadership styles, it has been found that the number of female leaders and their leadership tenure remain limited compared to men (Cem & Üste, 2023 From ancient times to the modern era, the concept of leadership has been shaped by male dominance, with women largely overlooked. However, the postmodern understanding of leadership, influenced by technological developments and globalization, has increased the visibility of women in leadership roles and diversified their opportunities (Cem & Üste, 2023).

Women's perception of leadership is influenced by social, cultural, and religious factors. A study conducted at Faculties of Theology in Turkey shows that Islamic approaches are compatible with contemporary management models in terms of women's perception of leadership (Çifçi, Aslan & Karabacak, 2015). Similarly, in countries such as Saudi Arabia and Jordan, women are demanding trust and responsibility by invoking religious and cultural norms; however, patriarchal social structures pose significant barriers that limit women's advancement to leadership positions (Alghofaily, 2019; Koburtay et al., 2023). Although women are underrepresented in social and local governance, they can demonstrate leadership potential by contributing to community safety and development (Hassan & Silong, 2008). However, African American women leaders' perceptions of leadership and empowerment vary due to ethnic and career differences, and their dual minority status can hinder their progress (Sales et al., 2020).

The obstacles women face in leadership roles are explained through concepts such as the glass ceiling and the glass cliff. While the glass ceiling is defined as an invisible barrier that limits the highest management level that women can reach, the glass cliff refers to the implicit discrimination that

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occurs when women are assigned to risky and crisis situations (Akbaş & Korkmaz, 2017; Sivrikaya & Wolff, 2021). Saudi women face challenges in reaching leadership positions due to gender-based discrimination and societal prejudices, but education, skill development, and cultural change are reducing these barriers and increasing the likelihood of success(Kattan, 2015). In Lebanon, women's leadership is constrained by patriarchal social norms and women's roles within the family rather than by organizational structures (Sidani, Konrad & Karam, 2015).

Research on women's leadership characteristics and styles shows that while women are mostly person and relationship oriented, men exhibit task-oriented leadership behaviors (Bayhan & Arslan, 2005).

Democratic and participatory leadership styles are approaches that women more often adopt, and women leaders also use conciliatory strategies and emphasize cooperation to improve group performance (Chapman, 1975; Uğurlu & Hovardaoğlu, 2011). However, it has been shown that organizations led by female CEOs tend to adopt more innovative and environmentally friendly practices, and female leadership contributes to corporate innovation and economic growth (Khushk,et al., 2023).

To make the subsection more structured, Table 1.10 summarizes the main explanatory lenses used in the literature on women's leadership, linking typical barriers, enabling conditions, and expected organizational outcomes.

Table 1.10 shows that women's leadership is best explained through interacting layers of context, barriers, and enabling mechanisms, rather than through simplified assumptions about gendered leadership styles.

Studies performed in Turkey reveal that female managers exhibit different leadership characteristics, most notably team spirit, communication skills, and individual competencies (Şencan et al., 2015). The team leadership roles of female school principals fall slightly below the expectations of assistant principals and teachers; there is a moderate, positive, and meaningful relationship between the level of display and the degree of importance (Selçuk et al., 2013). Furthermore, women's increasing participation in the workforce, its impact on leadership roles, and the challenges they face have been extensively researched, particularly through examples of academic leadership in higher education (Kütükcü, 2017; Onay & Heptazeler, 2014; Şencan et al., 2015).

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Table 1.10. Key lenses for analyzing women's leadership: barriers, enablers, and outcomes

Analytical lens	What it explains	Typical barriers highlighted	Enablers emphasized	Expected outcomes for organizations
Historical and institutional context	Why leadership roles were male-dominated over time	Normative exclusion; path dependence in elite selection	Policy reforms; representation targets; institutional accountability	More diverse leadership pipelines; legitimacy of inclusion
Socio-cultural and religious environment	How social norms shape leadership legitimacy	Patriarchal expectations; role conflict; stigma	Cultural reinterpretation; community support; education	Higher acceptance of women leaders; social trust gains
Glass ceiling mechanisms	Why women are blocked from senior roles	Invisible promotion barriers; biased evaluation	Transparent criteria; mentorship; sponsorship	Fairer promotion rates; stronger retention
Glass cliff dynamics	Why women are appointed in high-risk contexts	Crisis appointments; heightened scrutiny; short tenure	Risk-sharing governance; board support; role clarity	Reduced failure attribution bias; more stable tenures
Leadership style and behavior patterns	How leadership practices differ by context	Stereotyping of "fit"; penalization of assertiveness	Inclusive leadership norms; skill recognition	Better collaboration; stronger team performance
Innovation and sustainability links	Why female leadership may correlate with specific outcomes	Limited access to strategic resources	Resource access; executive development; decision authority	Higher innovation capacity; sustainability-oriented change

Sources: compiled by the author based on the subsection's cited literature.

As a result, women female leadership studies constitutes an important research issue both global and in our country. The barriers women face in leadership roles stem from cultural, social, and structural factors, nevertheless these barriers can be overcome through education, skill development, and social awareness. The innovative, communication-focused, and conciliatory approaches provided by women leaders increase the performance and innovation capacity of organizations; therefore, achieving gender equality is critical to the success of both women and institutions (De Nmark, 1993; Offermann & Foley, 2020; Eagly & Carli, 2003; Maheshwari, Nayak & Ngyyen, 2021; Baselga-Pascual & Vähämaa, 2021).

In summary, women's leadership should be interpreted as a socio-institutional phenomenon shaped by historically unequal access to authority,

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persistent cultural expectations, and structural constraints within organizations and societies. The reviewed arguments indicate that differences in leadership effectiveness are not determined by gender as such, but by opportunity structures that influence who is selected, promoted, supported, and evaluated as a leader. Cross-cultural evidence shows that social, religious, and community contexts can both legitimize women's leadership and simultaneously reproduce patriarchal restrictions that limit career progression. The concepts of the glass ceiling and the glass cliff remain useful for explaining why women are often prevented from reaching senior positions or are appointed under conditions of heightened risk and scrutiny. At the behavioral level, women's leadership is frequently associated with relational, participatory, and communication-centered practices, which can strengthen collaboration and organizational learning, while research also links female executive leadership with innovation and sustainability-oriented outcomes. However, the persistence of underrepresentation suggests that individual competence is insufficient without institutional reforms that address bias, role expectations, and unequal access to professional development. Therefore, gender equality in leadership should be treated as a strategic condition for organizational performance and social progress, requiring coordinated interventions in education, workplace policies, and cultural narratives that define leadership legitimacy.

3. The Impact of Digital Transformation in Businesses on Women's Leadership. Digital transformation, artificial intelligence, social media and information and communication technologies (ICT) tools strengthen women's leadership, reduce institutional barriers and contribute to gender equality through inclusive organizational culture and policies(Areiqat, 2024, s.1087; Wulandari & Ahmad, 2025, s.124). Developing women's technical knowledge, strategic thinking, and inclusive leadership competencies is critical for overcoming barriers in the sector and fostering innovation (McCall, 2024, p.1). Especially in regional and rural areas, digital transformation is a fundamental tool in the development of women entrepreneurs and SMEs, and social networks, workplace culture and perception of information technologies create a difference in the digital transformation of women-led SMEs compared to men (Alam vd., 2022, s.535; Hazudin vd., 2025, s.1). Rural women entrepreneurs can successfully implement their digital strategies thanks to digital leadership and entrepreneurial resilience (Hazudin et al., 2025, p.1). Furthermore, digital

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tools and social media offer significant opportunities for women entrepreneurs to overcome traditional gender barriers and digital pressures (Hazudin et al., 2021, p.1). Similarly, digital transformation enhances economic empowerment in micro, small, and medium-sized enterprises managed by women affiliated with Islamic organizations, thereby improving business performance and strengthening the impact of a resource-based approach through access, participation, control, and benefit (Azizah et al., 2024, p.71). While in Turkey, the empowerment of women in rural areas through digital entrepreneurship reduces the effects of male-dominated working life and regional inequalities, while in India, digital transformation plays a decisive role in the development of technology-focused business strategies by women entrepreneurs (Sak et al., 2023, p.91; Saranya & Chandrasekar, 2023, p.1).

While women leaders are still underrepresented in senior management and technology fields at the European and global levels, inclusive leadership programs and policy implementations are increasing female representation and organizational effectiveness (Górska & Burlakova, 2025, p.116; Mendoza et al., 2024, p.963). In the case of Japan, when the proportion of female executives is high, digital technology integration and ICT skills increase, and the presence of women in leadership positions positively impacts digital economy performance (Onozaka & Nemoto, 2023, p.155). Similarly, in New Zealand and Australia, digital tools, flexible working, and continuous learning are reducing women's representation at lower levels in the ICT sector (Skakun, 2024, p.1). Gender imbalance, structural biases, and inadequate support ecosystems in digital transformation projects affect both exclusion and innovation quality; diversity-focused leadership and inclusive practices are critical to reducing these barriers (Syahputra & Shabira, 2025, p.1; Weber-Lewerenz & Vasiliu-Feltes, 2022, p.117).

To clarify the logic of the subsection, Table 1.11 systematizes the main digital mechanisms influencing women’s leadership, the barriers that weaken these mechanisms, and the governance responses that convert digital opportunities into measurable inclusion outcomes.

Table 1.11 demonstrates that digital transformation strengthens women’s leadership through identifiable mechanisms, but the realized outcomes depend on whether organizations and policy systems remove skill, finance, and bias-related constraints through measurable and enforced inclusion practices.

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Table 1.11. Digital transformation mechanisms shaping women's leadership in business: pathways, constraints, and responses

Digital pathway	How it strengthens women's leadership	Typical constraints and risks	Governance and management responses
AI and data-driven tools	Improves decision quality, forecasting, and operational efficiency; supports strategic positioning	Algorithmic bias; unequal access to advanced tools; weak data literacy	Bias-aware AI governance; training in data and AI literacy; transparent accountability
Social media and digital platforms	Expands visibility, professional networks, customer reach, and branding	Online harassment; reputational vulnerability; platform dependency	Digital safety protocols; brand protection policies; platform diversification strategies
ICT-enabled flexible work	Reduces time and mobility constraints; supports continuity of work and leadership engagement	"Flexibility stigma"; blurred boundaries; uneven access to remote work roles	Fair workload design; performance metrics based on results; inclusive remote leadership norms
Digital entrepreneurship and e-commerce	Enables market entry and scaling for women-owned SMEs, including rural settings	Digital divide; limited logistics and payment infrastructure; skill gaps	Digital infrastructure investment; targeted SME support; mentoring and incubators
Inclusive digital culture and programs	Increases representation and effectiveness through structured inclusion	Tokenism; uneven implementation; resistance in male-dominated sectors	Formal inclusion KPIs; leadership development programs; promotion and pay transparency
Finance and digital capital	Supports growth, resilience, and investment capacity	Gender gaps in credit and investment; weaker networks for fundraising	Gender-responsive finance instruments; fintech inclusion; access-to-capital programs

Sources: compiled by the author based on the subsection's cited studies.

While digital transformation reshapes leadership and human behavior, the examination of women's leadership competencies has remained limited; therefore, strategic planning is required based on the economy, education, and sectoral policies (Al-Aali, Masmoudi & AlSaffar, 2024, p.18; Krchová & Höesová, 2021, p.524). Digital transformation and technology integration can increase the effects of female leadership on business resilience in a balanced way (Nikey, 2024, p.1). Equipping female students with digital transformation skills, developing their leadership and entrepreneurship competencies, and supporting economic performance and inclusive growth in the future business world (Zagar et al., 2023, p.1). While women entrepreneurs' intentions are influenced more by education and adaptability than by digitalization and financial constraints, gender inequality positively increases entrepreneurial intentions (Salman et al., 2025, p.199).

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Although women are represented in all roles and levels within the technology sector, their distribution varies depending on the type of organization and hierarchical level; this situation more realistically reveals women's role in technology management (Breßler et al., 2023, p. 1). Although women leaders are often positioned on the periphery in smart cities and e-government applications, their e-leadership in local government increases transparency, accountability, and participation; despite information and technology gaps, they demonstrate innovation and resilience (Asmorowati et al., 2025, p.1). Financial access and digital literacy are critical factors affecting the business growth of women entrepreneurs in the United Kingdom; women entrepreneurs are significantly disadvantaged compared to men in terms of access to investment and credit, and inclusive policies are required (Busari et al., 2025, p.1). Digital capital and digital skills development support women's advancement into leadership roles within organizations; bridging the digital divide strengthens women's leadership through individual and organizational factors (Thomas et al., 2024, p.513).

The reviewed evidence indicates that digital transformation functions as both an accelerator and a selective filter for women's leadership in business. On the one hand, the diffusion of artificial intelligence, social media, and ICT expands women's access to networks, market information, and scalable tools for visibility and value creation, which is especially consequential for women-owned SMEs and rural entrepreneurship where digital channels can compensate for infrastructural and geographic constraints. On the other hand, the same transformation reproduces inequality when digital capital, financial access, and skills development remain uneven, and when organizational cultures continue to embed structural bias into recruitment, promotion, and innovation governance. The findings therefore suggest that digitalization does not automatically translate into gender equality, but rather amplifies the outcomes of existing institutional conditions. When inclusive leadership programs, policy instruments, and organizational practices reduce entry barriers, strengthen capability building, and improve access to finance and infrastructure, women's leadership becomes more visible and influential, with positive spillovers for innovation quality, resilience, and sustainable growth. Conversely, where support ecosystems are weak, women may remain concentrated in lower hierarchical levels despite high participation in digital work. Accordingly, the strategic implication is that gender-responsive digital transformation requires coordinated interventions across the firm, sector, and

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policy levels, linking technology adoption with inclusion metrics, competency development, and resource accessibility.

Conclusions. The research demonstrates that digital transformation and women's leadership should be interpreted as interdependent phenomena that unfold across technological, organizational, and socio-institutional layers. Digital transformation is not limited to the adoption of artificial intelligence, platforms, or ICT tools, because it also reorganizes processes, decision rules, performance measurement, and the capability profiles expected from leaders. Within this reconfigured environment, women's leadership gains additional channels of influence through data-informed decision-making, network building, digital visibility, flexible work models, and entrepreneurial entry points, including in regional and rural contexts where digital access can compensate for structural market limitations. At the same time, the persistence of gender gaps confirms that technology alone does not dismantle institutional barriers, since biased evaluation practices, unequal access to finance and skills, and uneven support ecosystems can reproduce inequality within digitally transforming sectors. The analytical logic of the tables highlights that outcomes depend on whether organizations translate technological change into fair workflows, transparent promotion criteria, accountable governance, and inclusive capability development, rather than relying on informal gatekeeping or symbolic inclusion. Consequently, women's leadership should be treated as a strategic resource for innovation, sustainability, and resilience, but this potential becomes fully operational only under conditions of measurable inclusion and equal access to digital capital. The evidence also indicates that inclusive programs and policy instruments can shift representation and effectiveness when they are integrated with infrastructure investments, education pipelines, and organizational accountability mechanisms. Therefore, gender-responsive digital transformation requires coordinated interventions at the firm, ecosystem, and public governance levels, aligning technology adoption with concrete inclusion metrics, leadership development, and access-to-capital solutions. Under these conditions, digital transformation can function not merely as a productivity agenda, but as a practical pathway for reducing gender inequality while strengthening business competitiveness and long-term economic growth.

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Section 1.3. Security Aspects of Organizational Management and Ensuring Personnel Loyalty

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Abstract. *This study conceptualizes organizational security as a managerial prerequisite for stability and long-term performance. Security is treated not only as protection from external threats, but also as the systematic control of internal vulnerabilities that influence operational continuity and organizational trust. The objective is to explain how security instruments shape personnel loyalty by affecting employees' perceptions of protection, rule clarity, managerial competence, and organizational predictability. The analysis follows an integrative approach that compares three interrelated security dimensions, namely physical, information, and economic security, and interprets each through its expected loyalty effects. Illustrative regional examples and sectoral case logic, supported by SWOT profiling of Kyivstar and Motor Sich, are used to demonstrate how security and resilience configurations differ across industries. The findings indicate that physical security lowers perceived vulnerability, information security strengthens clarity of rules and confidence in managerial control, and economic security reinforces predictability and beliefs in organizational sustainability. Together, these dimensions support loyalty not only as an attitudinal construct, but also as observable behavior, including compliance, engagement, and proactive risk reporting. The case comparison suggests that telecommunications security priorities concentrate on competitive pressure and cybersecurity, while industrial resilience is more sensitive to political and regulatory uncertainty, requiring differentiated risk-management architectures. Public governance is identified as an enabling context that strengthens baseline security through regulatory clarity, monitoring capacity, support instruments, and competence diffusion, thereby indirectly reinforcing loyalty. Security-oriented management is most effective when it is systemic, evidence-based, and continuously improved through training, monitoring, audits, and feedback. Future research should validate integrated loyalty measurement models that combine attitudinal, behavioral, and risk-deviation indicators, and test how governance quality moderates the security–loyalty relationship across sectors and regions.*

Keywords: *organizational security; personnel loyalty; physical security; information security; economic security; security-oriented management; compliance behavior; risk reporting; resilience; public governance; SWOT analysis; measurement indicators.*

1. Conceptual foundations of organizational security and personnel loyalty. In the modern world, organizational security is one of the key factors determining stability and long-term success. Security aspects of management encompass not only physical protection but also information, economic, and social security. At the same time, ensuring personnel loyalty has become an essential component for achieving an organization's strategic objectives. This section examines how security considerations influence organizational management and contribute to the development of employee loyalty. The interrelation between security measures and personnel loyalty plays a decisive role in the effectiveness of any enterprise. Integrating security policies into the overall management strategy helps create a safe and supportive working environment, which in turn enhances employee loyalty, motivation, and productivity. In today's dynamic environment, attention to these aspects is critical for ensuring sustainable organizational development.

Organizational security in the context of management should be understood as a multi-dimensional system of measures and managerial decisions aimed at preventing losses, preserving the continuity of operations, and maintaining a predictable working environment. In this section, security is interpreted not only as protection from external threats, but also as the ability of the organization to control internal vulnerabilities, including errors, negligence, opportunistic behavior, and information leakage. Personnel loyalty is considered as a stable employee orientation toward the organization that is expressed in trust in management, willingness to comply with internal rules, engagement in achieving goals, and intention to remain in the organization. From a managerial perspective, security and loyalty form a reciprocal relationship: security policies shape perceptions of fairness, protection, and stability, while loyalty reduces insider risks, increases compliance, and supports disciplined performance. Therefore, the analytical task is to show how security instruments become not only protective mechanisms but also socio-organizational conditions that support loyalty and sustainable development.

2. Academic discourse on security-oriented management and loyalty. A number of Ukrainian scholars have addressed the issues of organizational management, ensuring its security, and maintaining personnel loyalty. The analysed studies may be grouped by several parameters into the following thematic blocks:

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1) ***Personnel security and labour potential development.*** This thematic block addresses risks of staff loss, workforce planning, and the strengthening of personnel resilience at the organizational and national levels. In particular, Antoniuk (2023) analyzes the loss of labour potential as a threat to post-war recovery and to national and personnel security. Matiukh, Korbut, Haiduk, and Rudnichenko (2025) conceptualize personnel security as a component of socio-economic stability at the enterprise level. Semenchenko (2020) interprets personnel planning as a managerial mechanism for minimizing HR-related risks and preventing кадрові загрози through proactive staffing decisions. Hobela and Korzhanevska (2023) emphasize the development of human capital as a determinant of economic security, linking workforce quality to organizational sustainability. Overall, the block highlights staff shortages, personnel risks, workforce planning, and human resource development as key drivers of organizational security.

2) ***Personnel loyalty, motivation, and internal marketing.*** This group focuses on mechanisms that shape loyalty, trust, and a constructive psychological climate within organizations. Bohoiavlenskyi (2017) emphasizes internal marketing tools, employer branding, and corporate culture as organizational instruments for strengthening employee commitment. Halko (2019) proposes a typology of loyalty that differentiates emotional, rational, and behavioral forms, and identifies determinants that influence loyalty formation. Mihus and Chernenko (2013) examine approaches to loyalty assessment and argue that loyalty affects economic security through retention, compliance, and reduced internal risks. Melnychuk, Voinalovych, and Zhyvko (2022) consider social insurance as a factor that supports social protection and contributes to loyalty by increasing perceived security and fairness. In synthesis, this block conceptualizes loyalty as a strategic factor of organizational stability, risk prevention, and security assurance.

3) ***Human resource management within the sustainable development paradigm.*** This block integrates ecological, social, and economic dimensions into HRM and interprets personnel management as a long-term sustainability mechanism. Boikivska, Ovcharuk, and Tkachenko (2024) develop a systemic approach to HRM oriented toward employee development and risk reduction, highlighting the role of responsible management practices. The emphasis is placed on sustainability principles, social responsibility, and the preservation of labour potential as a long-term organizational asset.

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*4) **Information security, cybersecurity, and digitalisation.*** Studies in this block show how digital environments transform organizational risks, control mechanisms, and security systems. Zhyvko and Rudyi (2020) analyze challenges of cybersecurity regulation and identify institutional gaps that increase vulnerability and compliance risks. Zhyvko and Zhyvko (2023) examine digitalization in economic security management and highlight the managerial implications of digital control systems. Kramarenko and Vyshnevska (2024) conceptualize digitalization through key theoretical approaches and discuss its challenges and development prospects. Skopenko, Kyrychenko, and Yevsieieva-Severyna (2023) emphasize the role of business digitalization in competitiveness while also pointing to emerging risks related to information leakage and operational dependence on digital infrastructures. Overall, this block covers information threats, cyber risks, and digital technologies as instruments for security management and for improving HR-related efficiency.

*5) **Quality management as a factor of safety and trust.*** This block demonstrates how quality standards and management systems increase organizational safety by strengthening predictability and transparency. Leskiv and Tymkiv (2023) discuss international ISO standards and interpret quality management as an institutional basis for trust and internal stability. The key idea is that process standardization enhances controllability, reduces uncertainty, and supports a stable organizational environment that is conducive to loyalty.

*6) **Risk management, stakeholder balance, and strategic security.*** This group explores organizational security through integrated risk management and the balancing of stakeholder interests. Zhyvko et al. (2019) argue that strategic management of financial and economic security requires balancing risks and protecting stakeholder interests as a precondition for stability. Rodchenko et al. (2022) develop a value-oriented approach to security in banking, emphasizing trust and stakeholder value as foundations of strategic security. In synthesis, this block supports an integrated risk-management approach in which trust and strategic loyalty function as core conditions for economic security.

The reviewed research demonstrates that Ukrainian scholarship provides a broad conceptual basis for understanding personnel security, loyalty mechanisms, sustainability-oriented HRM, and digital security challenges. At the same time, these thematic directions are often developed in parallel, which

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creates a methodological gap between security management as a protective function and loyalty management as a behavioral and cultural outcome. In practice, organizations need an integrated logic that links security dimensions with the mechanisms through which employees form trust, perceive organizational care, and make decisions about retention and compliance. This integration is especially important under conditions of uncertainty, when external shocks intensify the consequences of operational errors and increase the sensitivity of employees to safety, transparency, and predictability. Accordingly, further analysis should focus on the security dimensions that are most directly experienced by employees and most clearly transform managerial intentions into loyalty outcomes.

However, there is a range of issues that require immediate attention in order to ensure the economic security of a business. It is therefore essential to examine several key components of security-physical, informational, and economic-through the lens of personnel loyalty.

3. Analytical logic and scope of the section. To ensure analytical consistency, this section examines security through three interrelated dimensions that have the most direct impact on employees' daily work experience and on their trust in organizational stability: physical security, information security, and economic security. This choice is justified by the fact that these dimensions cover the protection of people and assets, the protection of data and managerial decisions, and the protection of financial continuity that underpins employment stability. The analysis is conducted through the lens of personnel loyalty, meaning that each dimension is assessed not only in terms of risk reduction, but also in terms of how it influences employees' perceptions of protection, fairness, competence of management, and predictability of organizational processes. Tables in the following subsections provide illustrative regional examples that demonstrate typical managerial instruments and contextual variations, while the subsequent cases and SWOT analysis show how security profiles shape organizational resilience and internal trust.

Physical security includes measures aimed at protecting facilities, equipment, and personnel from external threats. These measures may involve hiring security services, installing video surveillance systems, and implementing access control procedures. Properly functioning physical security systems reduce the risks of theft, vandalism, and other security breaches. Hence, physical security remains a vital foundation for safeguarding

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both organizational assets and human resources.

From the perspective of loyalty, physical security functions as a visible signal of organizational responsibility and managerial competence. When employees observe consistent 66ort h control, clear procedures, and adequate protection of facilities, they are more likely to perceive the organization as stable and to trust the capacity of management to protect both people and resources. This reduces anxiety and the subjective expectation of chaos, which is particularly important in environments characterized by elevated external risks. Physical safety also influences behavioral loyalty because employees become more willing to comply with internal rules when they believe that the organization applies standards systematically rather than selectively. In operational terms, the effectiveness of physical security can be monitored through incident frequency, compliance with 66 ort h procedures, and regularity of safety briefings, which together provide measurable signals of preventive discipline.

Table 1.13 presents illustrative examples of physical security measures used by enterprises in different regions of Ukraine to reduce exposure to external threats and strengthen the protection of facilities, equipment, and personnel.

Table 1.13. Examples of Physical Security Measures

№	Examples from the Western Region	Examples from the Eastern Region
	Security Services	
1	In Lviv, many businesses rely on private security companies to ensure safety. For example, shopping malls employ security guards who monitor the entry and exit of visitors, helping prevent theft.	In Kharkiv, due to elevated security risks, enterprises often hire military personnel or former law enforcement officers to guard their facilities, ensuring additional protection.
	Video Surveillance	
2	Video surveillance systems installed in restaurants and cafés in Ternopil allow owners to monitor operations inside the premises while also deterring potential offenders.	In Dnipro, especially in industrial zones, companies actively use video surveillance systems to monitor their territories, enabling a rapid response to emerging threats.
	Access Control Systems	
3	Large office centers in Ivano-Frankivsk use electronic access control systems that permit entry only to authorized individuals, reducing the likelihood of unauthorized access.	In Zaporizhzhia, where businesses often face vandalism risks, biometric access systems are used to protect sensitive areas.

Sources: compiled by the authors

The comparison between the Western and Eastern regions highlights how similar security instruments are implemented with different intensity and staffing models depending on the local risk environment. By systematizing these practices, the table clarifies the practical toolkit through which organizations institutionalize preventive control and maintain safe operational conditions.

The examples demonstrate that physical security is achieved through a combination of human guarding, surveillance technologies, and access control systems, with regional differences reflecting variations in threat levels and operational priorities. These measures reduce the probability of theft, vandalism, and unauthorized entry, while also strengthening employees' perceptions of safety and organizational reliability.

4. Information security, cybersecurity, and loyalty as compliance behavior. Information security is a critical component of organizational management, as data is considered a strategic asset. To prevent the leakage of confidential information, organizations must implement comprehensive information protection policies, including encryption, the use of antivirus software, and employee training. Failure to provide adequate information security can result in significant reputational and financial damage.

Information security influences loyalty primarily by forming a trust-based compliance environment. Employees demonstrate stronger commitment when they clearly understand information security rules, observe that management protects both corporate and personal data, and see that incidents are handled professionally without unfairly shifting responsibility onto individuals. By contrast, weak cybersecurity and unclear policies increase uncertainty and may create a blame-oriented climate that reduces engagement and can encourage opportunistic behavior. In this dimension, loyalty is expressed through disciplined adherence to digital procedures, careful handling of documents and access credentials, and willingness to report suspicious activity rather than conceal it. For managerial monitoring, relevant indicators include training coverage and assessment results, the frequency of phishing incidents, the number of policy violations, and the time required to detect and respond to security events.

Table 1.14 summarizes practical information security measures applied by enterprises in different regions of Ukraine to protect confidential data, reduce cybersecurity exposure, and maintain the integrity of digital operations. The regional comparison illustrates how organizations adapt similar instruments, such as encryption, endpoint protection, and personnel training, to their dominant risk profiles and sectoral specifics. By presenting

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these examples in a structured format, the table clarifies the operational toolkit through which information security is embedded into everyday management routines.

Table 1.14. Examples of Information Security Measures

№	Examples from the Western Region	Examples from the Eastern Region
1	Data Encryption	
	Companies handling financial information in Lviv adopt encryption technologies to protect client data and prevent information leaks.	IT companies in Kharkiv actively apply encryption to safeguard software assets and confidential client information.
2	Antivirus Software	
	Western-region companies regularly update antivirus software to protect critical data from cyber threats and malware attacks.	Large manufacturing enterprises in Dnipro maintain systematic antivirus updates to ensure ongoing protection against cyber risks.
3	Personnel Training	
	Organizations in Khmelnytskyi conduct regular employee training sessions focused on data security, raising awareness of potential risks and prevention methods.	In Kropyvnytskyi, companies organize online seminars teaching employees how to identify phishing attempts and other cyber threats.

Sources: compiled by the authors

The examples demonstrate that effective information security relies on a combined approach that integrates technological safeguards and systematic human-capacity development. Encryption and regularly updated antivirus solutions reduce the probability of data leakage and malware-related disruption, while continuous training strengthens employees' ability to recognize and prevent threats such as phishing.

2. Economic security as a basis for retention and organizational trust. Economic security of an organization encompasses the management of financial risks and the maintenance of stable financial flows. Key components of economic security include systematic monitoring of market conditions, effective accounts receivable administration, and the implementation of anti-crisis measures. A resilient economic foundation ensures that an organization can invest in strategic development and strengthen personnel loyalty (Table 1.15).

Economic security affects loyalty through perceptions of employment stability, fairness of reward, and predictability of the organization's future. When the enterprise demonstrates reliable cash flow management, disciplined accounts receivable control, and crisis preparedness, employees interpret this as the ability of management to protect jobs, wages, and working conditions.

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Table 1.15. Examples of Economic Security Measures

№	Examples from the Western Region	Examples from the Eastern Region
1	Monitoring of Market Conditions	
	Businesses in Lviv actively analyze market trends to adapt their strategies to evolving conditions, reducing uncertainty and mitigating financial risks.	Export-oriented enterprises in Kharkiv continuously track exchange rate fluctuations to prevent potential financial losses.
2	Accounts Receivable Management	
	Organizations in Ternopil implement structured accounts receivable management systems that improve payment control and reduce the risk of overdue obligations.	Companies in Dnipro employ automated systems to manage payment schedules, ensuring consistent cash flow stability.
3	Anti-Crisis Measures	
	Enterprises in Lviv develop crisis-response frameworks that involve cost reduction and process optimization during periods of economic instability.	In Kropyvnytskyi, diversification programs are utilized to reduce dependence on a single market and mitigate associated risks.

Sources: compiled by the authors

Such perceptions strengthen retention intentions because employees link their personal well-being with the sustainability of the organization. Conversely, financial instability, payment delays, and chaotic anti-crisis decisions undermine trust and increase turnover risks, even when formal compensation levels remain unchanged. In the evaluation of this dimension, managers should monitor not only financial ratios, but also operational indicators that reflect stability from the employee's perspective, including regularity of wage payments, frequency of emergency cost cuts, workload volatility, and turnover dynamics.

Ensuring physical, information, and economic security represents a crucial prerequisite for stable organizational functioning across Ukraine. The implementation of comprehensive security measures not only protects material and intangible assets but also enhances employee loyalty, strengthening strategic resilience and organizational capacity.

The three security dimensions considered above form a unified managerial logic that directly influences personnel loyalty. Physical security reduces perceived vulnerability and supports basic confidence in organizational protection. Information security establishes rule clarity and strengthens trust in the competence and fairness of managerial control in the digital environment. Economic security ensures predictability and reinforces employees' belief that the organization can sustain operations and obligations over time. Together, these dimensions create a stable and transparent environment in which loyalty is expressed not only as emotional attachment

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but also as disciplined compliance, proactive risk reporting, and sustained engagement. To demonstrate how security profiles manifest in different sectors and how they shape organizational resilience, the next subsection applies SWOT analysis to Kyivstar and Motor Sich as illustrative cases.

SWOT Analysis of Kyivstar (Figure 1.3).

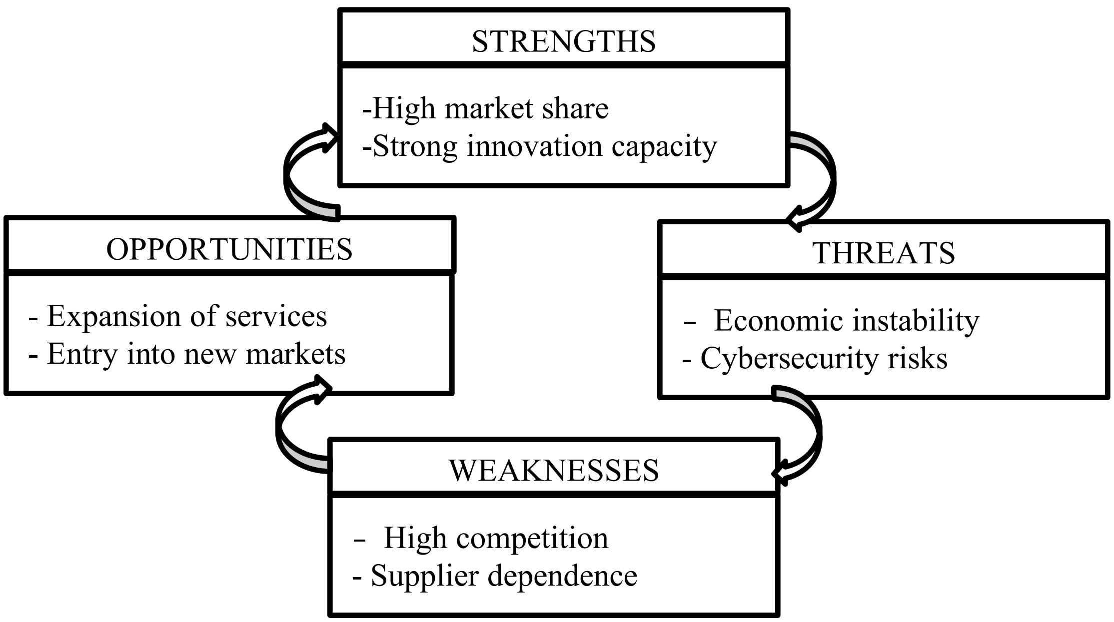

Figure 1.3. SWOT Analysis of Kyivstar

Sources: compiled by the authors

Kyivstar's competitive position is supported by several internal strengths that reinforce its resilience in the Ukrainian telecommunications market. A high market share indicates strong brand recognition and customer trust, while a well-developed infrastructure, including an extensive network of base stations, enables stable connectivity and consistent service quality. In addition, the company's continuous adoption of advanced technologies, particularly the rollout and upgrading of 4G and 5G solutions, strengthens its innovative profile and allows it to maintain competitiveness through improved network performance and new digital service capabilities.

At the same time, Kyivstar operates in a highly competitive environment where several major market players intensify price rivalry, which can compress margins and increase customer churn risk. The company is also

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exposed to supply-side vulnerabilities, as dependence on external suppliers of equipment and technology creates operational and strategic risks, especially under conditions of geopolitical uncertainty and potential disruptions in global supply chains.

Despite these constraints, Kyivstar has significant growth opportunities. The expansion of service portfolios, including mobile financial solutions and other value-added digital products, could increase customer retention and diversify revenue streams beyond traditional voice and data services. Moreover, entry into regions with lower mobile communication penetration offers a pathway for market expansion and infrastructure-driven growth, particularly if such regions demonstrate rising demand for reliable digital connectivity.

However, external threats remain substantial. Economic instability may reduce households' purchasing power and constrain demand for higher-priced packages or premium services. In parallel, cyber threats represent an escalating risk, as telecommunications infrastructure is a strategic target for cyberattacks, which can undermine service continuity, reputational capital, and trust among users and institutional partners.

SWOT Analysis of Motor Sich (Figure 1.4).

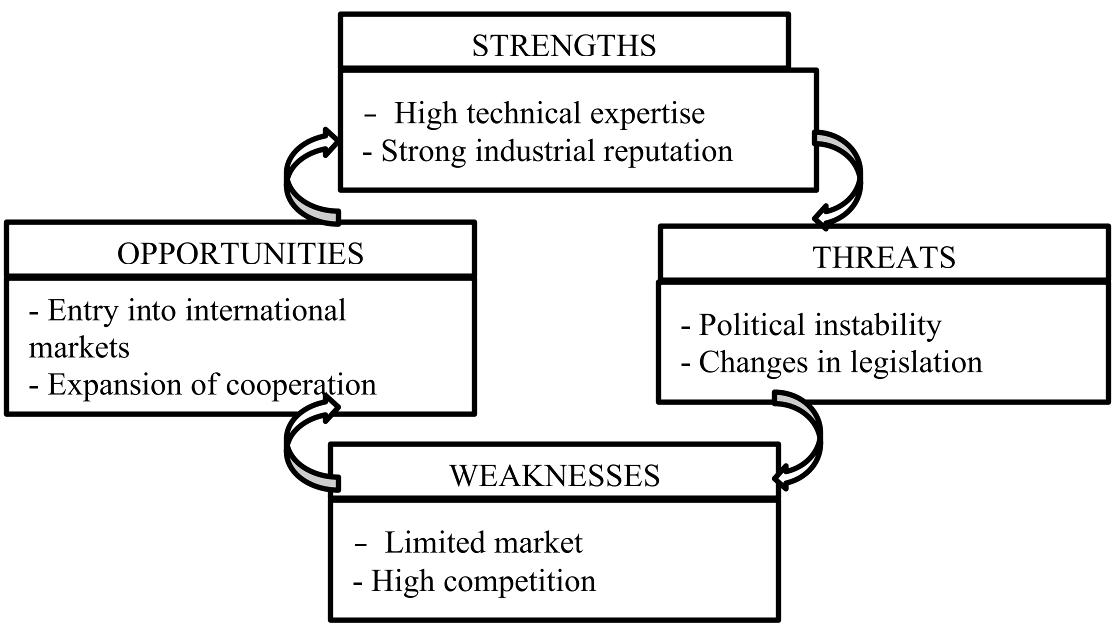

Figure 1.4. SWOT Analysis of Motor Sich

Sources: compiled by the authors

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Motor Sich's strategic position is anchored in a set of internal strengths that reflect both accumulated industrial capability and a strong technological profile. As a leading manufacturer of aircraft engines, the company benefits from substantial technical expertise and long-term sector experience, which supports stable production competence and creates high entry barriers for weaker competitors. Its strong international reputation, largely associated with the perceived quality and reliability of its products, functions as an important intangible asset that strengthens credibility in external markets. In addition, significant investment in research and development supports innovation, facilitates technological upgrading, and enhances the firm's capacity to adapt products to evolving performance and safety requirements in the aerospace industry.

At the same time, Motor Sich faces structural weaknesses that constrain strategic flexibility. A limited market orientation, shaped by dependence on defense-related orders and a relatively narrow client base, increases vulnerability to demand shocks and to changes in procurement policies. Competitive pressure from international manufacturers may further reduce profitability and market share, particularly in segments where global players have stronger access to capital, broader service ecosystems, or more diversified customer portfolios.

Despite these limitations, Motor Sich retains clear growth opportunities. Expansion into new markets creates potential for export diversification and for reducing dependence on a restricted set of buyers, which would strengthen revenue stability. Collaboration with international companies also offers an avenue for joint projects, technology transfer, and participation in global value chains, thereby increasing the company's innovation capacity and access to broader distribution channels.

However, the external threat environment remains substantial. Political instability can disrupt production processes and supply chains, complicate long-term planning, and raise transaction costs. In addition, unpredictable regulatory changes may negatively affect operational conditions, compliance burdens, and export procedures, which can limit the effectiveness of market expansion strategies and increase uncertainty for investors and partners.

Table 1.16 provides a comparative profile of Kyivstar and Motor Sich in order to illustrate how sector-specific contexts shape organizational strengths, vulnerabilities, growth options, and threat exposure. By presenting the core SWOT dimensions side by side, the table clarifies the different configurations

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of competitiveness and risk that management must address in telecommunications versus aircraft engine manufacturing. This comparison supports a more structured interpretation of security challenges and resilience factors, because it highlights how market dynamics, technological dependence, and regulatory environments influence strategic choices and organizational stability.

Table 1.16. Comparative Analysis of Kyivstar and Motor Sich

Criterion	Kyivstar	Motor Sich
Field of Activity	Mobile telecommunications	Aircraft engine manufacturing
Strengths	Strong market position; technological innovation	Technical expertise; strong industrial legacy
Weaknesses	High competition; dependence on suppliers	Limited market; increased industry competition
Opportunities	Service diversification; entry into new segments	International partnerships; new market integration
Threats	Economic instability; cybersecurity threats	Political risks; regulatory changes

Sources: compiled by the authors

Overall, the comparison indicates that Kyivstar's strategic priorities are shaped mainly by competitive pressure and cybersecurity risks in a technology-intensive service market, whereas Motor Sich's resilience depends on managing political and regulatory uncertainty in an industrial sector with narrower demand structure. Consequently, both organizations require differentiated security and risk-management approaches aligned with their specific threat profiles and development opportunities.

Organizational security and personnel loyalty are influenced not only by internal management practices but also by the external governance environment. Public regulation, inspection mechanisms, and state-supported infrastructure shape the baseline level of safety standards and determine the predictability of rules for business operations. When public governance ensures clear legal requirements, consistent monitoring, and accessible support instruments, organizations can institutionalize security policies more effectively and reduce uncertainty for employees. This strengthens loyalty indirectly because employees perceive the organization as operating within a legitimate, predictable, and socially protected framework. Therefore, the governance dimension should be included as an enabling context that amplifies or constrains internal security management.

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Figure 1.5 illustrates how public governance influences business security by shaping the external institutional environment in which enterprises operate. It summarizes the main governance functions that determine the predictability of rules, the enforceability of standards, and the availability of supportive instruments for organizations. In this logic, business security is not produced solely by internal management practices, because regulatory clarity, monitoring capacity, and public investments directly affect corporate risk exposure and the feasibility of preventive measures.

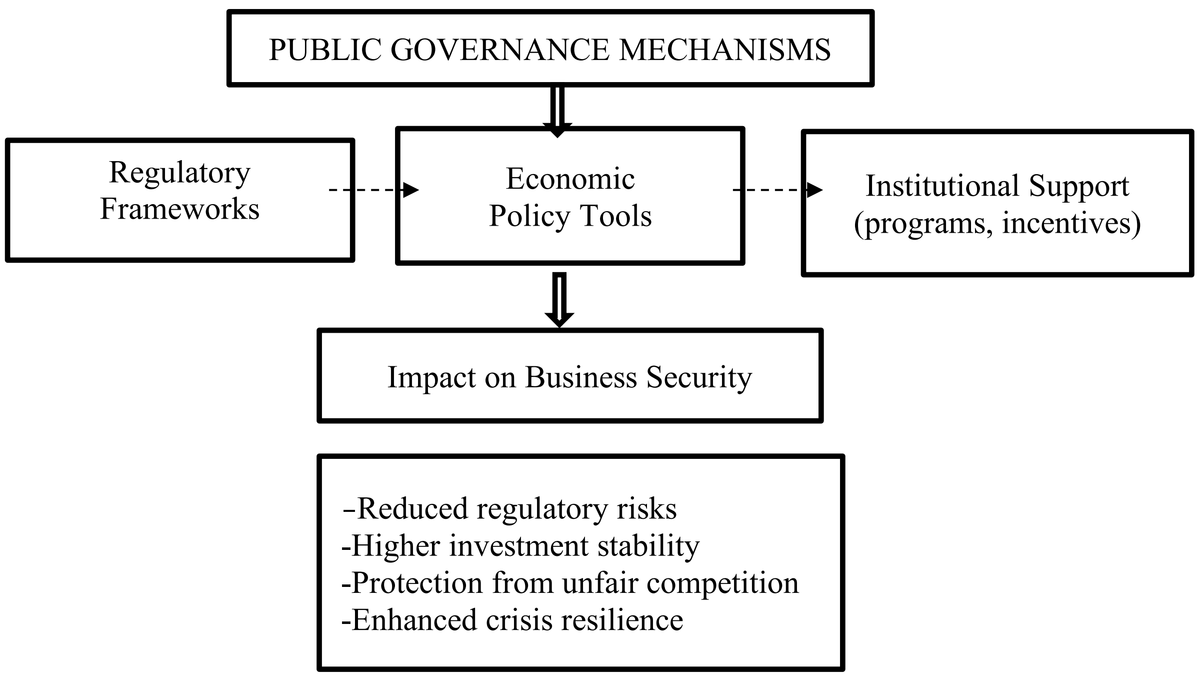

Figure 1.5. Influence of Public Governance on Business Security

Sources: compiled by the authors

Overall, the figure 1.5 demonstrates that effective public governance strengthens business security by combining regulation, oversight, support mechanisms, and awareness-building into a coherent policy framework. This integrated influence reduces uncertainty, improves compliance discipline, and creates conditions under which organizations can sustain stable operations and reinforce trust among employees and stakeholders.

Figure 1.6 presents the structural components of a state governance model aimed at ensuring a safe and enabling environment for business

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activity. The figure systematizes the key functional blocks through which public authorities shape security conditions for enterprises, including the formation of rules, enforcement mechanisms, resource support, and capacity building. This visualization is used to clarify that business security is partly determined by institutional design and by the consistency with which governance functions are implemented.

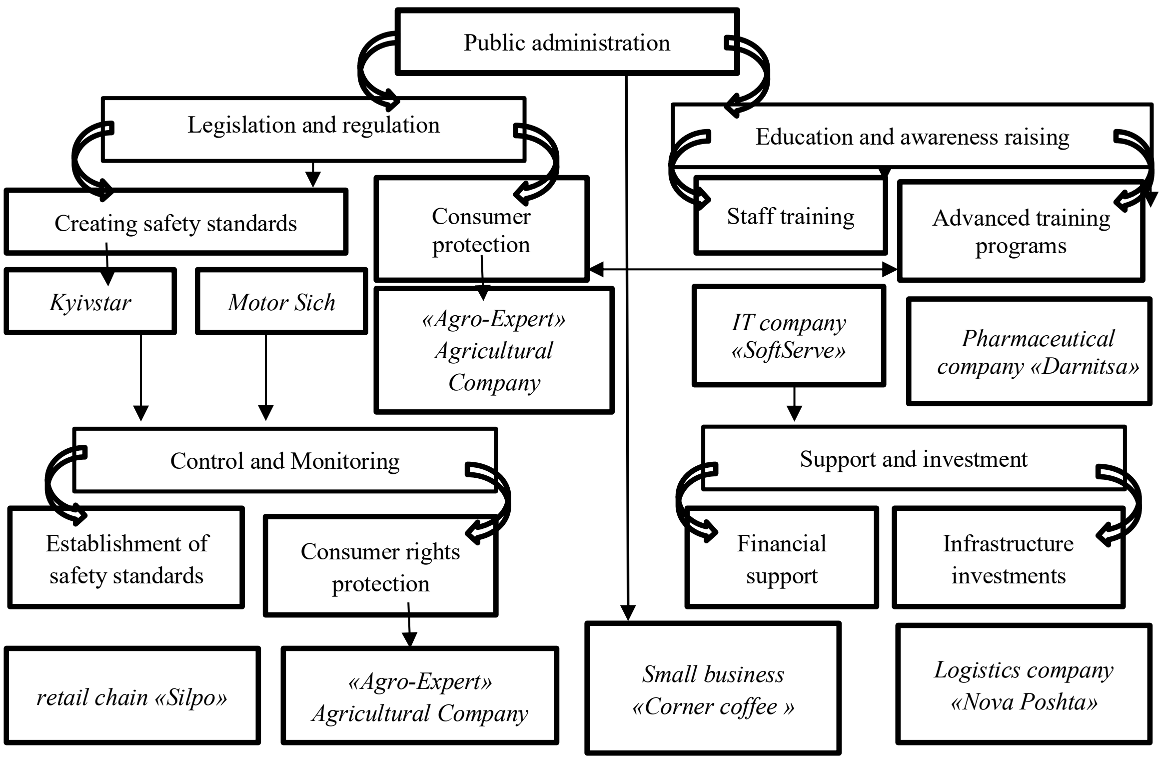

Figure 1.6. Components of the State governance model for business
Sources: compiled by the authors

Figure 1.6 demonstrates that a comprehensive state governance model for business security requires the coordinated interaction of regulatory, supervisory, supportive, and educational components. When these elements function coherently, they reduce uncertainty, strengthen compliance, and enhance organizational resilience, thereby indirectly supporting personnel trust and long-term business sustainability.

A public governance model aimed at ensuring business security can be interpreted as an integrated set of state functions that jointly create a

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predictable, safe, and enabling environment for enterprises. Its value lies in the fact that business security is not formed exclusively within organizations, because regulatory clarity, enforcement capacity, public investment, and the diffusion of professional knowledge shape the baseline conditions in which firms manage risks. At the same time, the model is adaptable, because industries face different threat profiles, regulatory burdens, and resource constraints, meaning that the same governance functions can be applied with varying intensity and instruments depending on sectoral and organizational needs.

Within this model, legislation and regulation form the institutional foundation by establishing mandatory standards for occupational safety, environmental protection, and consumer rights. These norms define minimum acceptable practices and create legal predictability for enterprises, as illustrated by the requirement that companies such as Kyivstar and Motor Sich comply with state-regulated safety and compliance standards. Control and monitoring then operationalize regulation through inspections and independent audits that verify compliance and identify systemic vulnerabilities. For example, the Silpo retail chain is subject to food safety inspections, while industrial enterprises such as Zaporizhstal may undergo safety audits that assess the reliability of production processes and the adequacy of risk controls. Support and investment complement enforcement by expanding firms' capacity to implement safety improvements through financial assistance, grants, and public infrastructure development. This includes targeted support for small businesses, such as grants for equipment modernization, as well as broader investments that strengthen logistics and transport systems, which can be critical for companies such as Nova Poshta. Finally, education and awareness raising strengthen the human and managerial dimension of security, because training programs and professional development initiatives increase competence and improve the quality of everyday decisions. Cybersecurity training implemented in IT firms such as SoftServe and risk-management sessions organized in companies such as Darnytsia illustrate how knowledge-based interventions reduce errors and strengthen a prevention-oriented culture.

The combined effect of legislative, supervisory, investment, and educational dimensions is the formation of a safer business environment that supports sustainable development and indirectly influences personnel loyalty. Personnel loyalty can be defined as employees' commitment to the

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organization, their willingness to contribute to its success, and their intention to remain in the company, which is typically associated with lower turnover, higher productivity, and a stronger corporate culture. Loyalty formation depends on several managerial factors, including transparent communication that builds trust, working conditions that support well-being and development, and recognition and reward systems that reinforce motivation and perceptions of fairness. In this context, security and loyalty are closely interconnected, because when employees experience the organization as safe, predictable, and socially responsible, their trust in management increases and they are more inclined to remain committed. Conversely, weak security generates anxiety and uncertainty that undermine motivation, compliance, and performance.

To manage loyalty as a security-relevant variable, organizations should measure it through a combination of attitudinal and behavioral indicators. Attitudinal metrics include trust in management, perceived safety climate, perceived fairness of rules, and perceived organizational stability, which can be captured through standardized surveys. Behavioral indicators include disciplined participation in training, voluntary compliance with procedures, accurate document handling, and a willingness to report security incidents rather than conceal them. Loyalty should also be assessed through retention-related measures such as turnover rates, turnover intention, absence patterns, and internal mobility, because these reveal long-term commitment and organizational attractiveness. A security-oriented approach additionally requires monitoring negative manifestations, including repeated policy violations, deliberate concealment of incidents, increased conflict frequency, and anomalous user behavior in digital systems. When these indicators are integrated, loyalty becomes a measurable managerial factor that contributes to organizational resilience, strengthens economic security, and supports stable development under uncertainty.

Conclusion. Organizational security should be treated as a unified managerial logic in which physical, information, and economic safeguards reinforce one another and shape personnel loyalty through perceived protection, rule clarity, and operational predictability. Within this integrated view, loyalty is expressed not only as a positive attitude toward the employer, but also as disciplined compliance with procedures, willingness to report risks, and sustained engagement in 77ort work, which transforms loyalty into a practical resource of organizational resilience. At the same time, security outcomes depend on more than internal managerial decisions, because the

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quality of public governance influences baseline conditions through regulatory clarity, enforcement capacity, support instruments, and the diffusion of security-related competencies. Consequently, enterprises strengthen security and loyalty most effectively when they align internal controls with external requirements and translate security expectations into transparent routines, systematic training, and continuous monitoring.

Managing loyalty in a security context also requires measurement tools that connect attitudinal indicators with behavioral signals and risk-relevant deviations. This makes it possible to track trust and commitment together with compliance discipline, incident prevention, and early warning signs of internal vulnerability. From this perspective, investments in security become a strategic choice that improves job satisfaction and retention not only by providing material protection, but also by strengthening employees' confidence in organizational stability, fairness, and responsibility. Overall, security-oriented management is most robust when it is systemic, evidence-based, and continuously improved through learning from incidents, audits, and feedback. Such an approach enhances organizational resilience, reduces the cost of errors, supports workforce engagement, and contributes to sustainable competitive advantage under conditions of uncertainty.

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Section 1.4. System for Evaluating the Management of a Company's Foreign Economic Activity

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Abstract. *This study conceptualizes the management of a company's foreign economic activity as an integrated governance system that connects strategic market choices with operational execution, financial and legal safeguards, logistics coordination, quality assurance, and competency development. The topic is relevant because cross border operations amplify the cost of errors in documentation and timing, while increasing exposure to regulatory complexity, volatile demand, and liquidity pressure. The objective is to clarify the modern concept of foreign economic activity management, to explain how digitalization restructures the managerial circuit, and to justify the role of artificial intelligence technologies as decision support instruments that strengthen both adoption and implementation of managerial actions. Methodologically, the study applies a conceptual and process based synthesis of management functions and control points across the end to end foreign trade workflow, from partner and market selection to settlement control and after sales support. It also uses a systems logic to connect process discipline with outcome stability, emphasizing traceable responsibilities, standardized documentation routines, and measurable performance signals. The main results show that digitalization shifts foreign economic activity from fragmented manual coordination to a managed, transparent, and traceable mode, where contract status visibility, approval speed, and documentary accuracy reduce operational losses and enhance predictability of costs and cash flows. Artificial intelligence technologies complement this shift by enabling early warning of risks, causal analytics of deviations, demand and delivery forecasting, and scenario planning, while also automating routine checks and reconciliations that increase execution accuracy. The combined effect of system management, digitalization, and AI enabled analytics forms a practical competitive advantage by improving reliability, reducing the price of mistakes, and strengthening financial resilience in international markets.*

Keywords. *management of foreign economic activities; modern management concept; security; management system; management decision-making; digitalization.*

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1. Foreign Economic Activity as a Driver of Enterprise Resilience, Competitiveness, and Organizational Maturity. Foreign economic activity for an enterprise today is not just an additional direction, but a way to remain relevant in an environment where demand, competition and logistics are rapidly changing under the influence of global events, technological shifts and fluctuations in resource prices. When the domestic market is saturated, growth rates slow down or consumer habits change, entering international sales channels gives the business new sources of income and the opportunity to expand the «horizon» of planning. The importance here is that the enterprise ceases to be tied only to local cycles, seasonality and limited purchasing power, but instead gets a chance to work with different customer groups, different quality standards and different cultural logics of consumption. The very fact of presence in foreign markets increases the company's resilience, because a decline in one region can be partially offset by growth in another, and the sales portfolio becomes more balanced. In addition, for many industries, international interaction has already become the norm, partners expect transparent conditions, predictable deadlines, documentary discipline and compliance with safety, quality and ethics requirements from the supplier, and the company that has mastered this automatically rises to a higher level of trust.

Competition in international markets is usually tougher, and therefore, the company is forced to put processes in order, calculate costs more accurately, control quality better, and improve products and service faster. This creates a «pull-up» effect for the entire business, because the requirements of importers, retail chains and industrial buyers often include not only product parameters, but also batch traceability, stability of characteristics, packaging standards, labeling requirements, warranty obligations and continuity of supplies (Tulchynska et al.., 2021). At the same time, innovation increases, because the company gains access to new practices, technological solutions and market information that is difficult to obtain working exclusively within the country (Nesterova et al.., 2020). Going abroad often changes management thinking, instead of short-term solutions, there is an orientation towards brand, reputation, long-term relationships and investments in product development. Moreover, foreign markets help to find a niche where a local product has special value, for example due to unique properties, design, raw materials, artisanal quality or flexibility of the manufacturer, and this allows the company not to fight only on price, but to

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compete on the basis of value. No less important is the financial and operational logic, which explains why foreign economic activity is worth the effort. For example, it opens up access to a wider range of suppliers and can reduce dependence on a single source of raw materials or components, which is especially critical in periods of shortages or price spikes. It also allows for better utilization of production capacities when domestic demand subsides and excess capacity turns into costs that «eat up» profits. Thirdly, international operations provide tools for more flexible cash flow management, as various payment terms, advances, letters of credit, deferrals and factoring solutions can be adjusted to the riskiness of the transaction and the needs of the enterprise. Of course, more complex risks also appear, currency fluctuations, customs procedures, delays at borders, differences in legal requirements, and the risk of non-payment, but that is why foreign economic activity stimulates the company to build mature mechanisms for risk management, responsibility allocation and control. When an enterprise learns to work with contracts, clear specifications, cargo insurance, counterparty checks and financial guarantees, it simultaneously becomes stronger in the domestic market, because discipline, predictability and quality of management decisions increase.

Thus, the importance of foreign economic activity is explained by the fact that it forms a new level of organizational maturity for the enterprise and opens up prospects that cannot be obtained without international interaction. Thus, this applies to personnel competencies, language skills, negotiation skills, logistical expertise, financial and legal support, as well as the ability to work with regulatory requirements, certifications and compliance requirements. Investments in these competencies are returned not only by contracts, but also by the fact that the company begins to work systematically, with transparent processes, clear rules and responsibility, which reduces internal losses and conflicts. Additionally, international presence strengthens the employer brand, attracts stronger specialists, provides an opportunity to build partnerships with foreign companies, participate in exhibitions, cooperation programs and joint projects that increase the technological level. In the end, the answer to the question «why» is simple and practical, because foreign economic activity increases growth opportunities, makes business more resistant to local shocks, increases competitiveness and the quality of management, and also opens up access to resources, knowledge, and markets, without which it is increasingly difficult to maintain a strong position in the modern economy.

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The arguments above show that foreign economic activity increases growth opportunities but simultaneously increases managerial complexity. Therefore, the central analytical task is to define what exactly should be managed, at which levels, and by which principles, so that international operations remain predictable and scalable. This requires a modern interpretation of foreign economic activity management as an integrated system rather than a set of isolated transactions. The next section clarifies this concept and specifies the governance components that later become measurable within an evaluation framework.

2. The essence of the modern concept of managing the foreign economic activities of an enterprise. Management of the foreign economic activity of an enterprise is a system of purposeful management decisions and actions that ensures the planning, organization, coordination and control of all operations of an enterprise related to international markets. If foreign economic activity for the executor sometimes looks like a set of contracts, invoices, customs declarations and transportation, then for management it is a full cycle of creating a result, from choosing a market and partner to receiving payment, post-delivery support and maintaining long-term relationships. The essence of such management is to turn international operations into a predictable and repeatable process, where each step has logic, a responsible person, deadlines, a set of documents and quality criteria. In international transactions, an error rarely remains small, because it quickly turns into delays at the border, additional storage costs, fines, missed deadlines, customer claims or the risk of non-payment (Viknianska et al., 2021). That is why foreign trade management means creating rules of the game within the enterprise that help avoid losses, and also help scale the international direction without chaos, when the growth of volumes does not lead to a proportional increase in errors. In a practical sense, this is managing how the enterprise enters the foreign market, how it sells or purchases, how it provides logistics, how it executes documents, how it protects its own financial interests and how it builds a reputation in the international arena. In a broader sense, foreign trade management includes a strategic level, where the enterprise determines why it needs an international direction, what goals it must fulfill and which markets are priority. This is not only the choice of the country, it is the choice of the entry model, direct export, work through a distributor, participation in tenders, the creation of joint projects, contract manufacturing or import of critical resources (Rudnichenko et al..2021). The strategic level answers the

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questions of who our client is abroad, what problem we solve, what is our advantage, how we will maintain quality and deadlines, and how we will differ from competitors. Here, the logic of the product portfolio is formed, what the company is ready to standardize for mass export, and what needs to be adapted to local requirements, for example, to other technical standards, other packaging requirements, other labeling or other service. An important part becomes the pricing policy, which includes not only the desired margin, but also the real costs of delivery, insurance, certification, financial commissions and payment terms. At this level, management also means a balance of risks, the company consciously determines how much risk it is willing to take in exchange for the possibility of growth, for example, in terms of deferred payment, currency risk or dependence on a separate market. Without such a strategic block, foreign economic activity often becomes reactive, the company «grabs» random opportunities, but does not gain stability and does not build a long-term position.

For analytical purposes, foreign economic activity management should be distinguished at three levels. The strategic level defines target markets, entry models, and value propositions, and it sets acceptable risk and return parameters. The tactical level translates strategy into market plans, partner portfolios, pricing rules, and resource allocation across functions. The operational level ensures contract execution through standardized procedures, document discipline, logistics coordination, settlement monitoring, and after sales support. Such differentiation is necessary because evaluation criteria vary by level and should not be mixed within a single undifferentiated score. (Table 1.17).

The principles summarized in Table 1.1 imply that effective management must be observable through outcomes and through the quality of processes that produce these outcomes. Consequently, evaluation should include indicators of strategic coherence, process reliability, risk and compliance performance, and economic efficiency. In international operations, purely financial metrics are insufficient because high revenue can coexist with weak document control, elevated payment default risk, or unstable delivery performance.

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Table 1.17. Essential principles for understanding the concept of foreign economic activity management

Foundation (conceptual focus)	Extended explanation
Strategic integration of foreign economic activity into corporate governance and competitive positioning	Foreign economic activity management is understood as a long term, enterprise wide governance model rather than a set of isolated export or import transactions. It aligns international market choices with the firm's mission, value proposition, and competitive advantages, and it connects external growth goals with internal capabilities such as production capacity, quality assurance, financial resilience, and human resources. In this view, decisions about target markets, entry modes, product adaptation, and partner selection are treated as strategic commitments that shape reputation, risk exposure, and resource allocation
Process based coordination across functions and end to end control of international transactions	The concept is grounded in a process approach that treats each international deal as an end to end workflow with defined stages, roles, documents, deadlines, and control points. It covers market intelligence, partner screening, offer preparation, contractual specification, pricing with full cost visibility, production planning, quality control before shipment, logistics coordination, customs documentation, settlement monitoring, and after sales support. Managing foreign economic activity therefore requires cross functional coordination between sales, procurement, production, logistics, finance, and legal teams, supported by internal procedures and standardized templates
Risk oriented and compliance centered management of regulatory, contractual, financial, and operational exposure	A core foundation is the integration of risk management and compliance into everyday operations, because international transactions involve multiple jurisdictions, regulatory requirements, and higher costs of error. The concept includes customs and tax compliance, rules of origin, certification and labeling requirements, contractual risk allocation, transport and cargo insurance, and safeguards against payment default. It also addresses financial exposure through currency risk awareness, liquidity planning, credit limits, and the selection of settlement instruments that match counterparty risk
Data driven decision support, digital enablement, and organizational capability building for scalability and resilience	The modern concept assumes that effective management depends on reliable data, digital workflows, and continuous capability development. Digital tools and integrated information systems improve traceability, shorten approval cycles, reduce documentary errors, and provide management visibility into contract status, logistics milestones, cost drivers, and receivables. On this basis, analytics and technologies on the basis of artificial intelligence can support forecasting, scenario planning, anomaly detection, and early warning signals, helping managers choose actions that are both faster and more evidence based

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Therefore, the assessment logic must combine result indicators with leading indicators that signal future disruptions. This methodological requirement creates the bridge to the digitalization section, because digital workflows provide the data basis for measuring both results and process quality consistently.

The modern concept also describes foreign economic activity as working with value chains, where not only the company's own operations are important, but also the quality, reliability and discipline of all participants standing nearby. If a company imports raw materials or components, then it actually depends on a foreign supplier, transport system, warehouses, customs brokers and banks, and therefore must manage interaction with them as a single system (Navickas et al.., 2016). If a company exports, then it depends not only on its own production, but also on the clarity of packaging, marking, correctness of documents, the quality of the carrier's work, and the conditions for accepting cargo on the partner's side. The modern approach is to have alternatives, backup routes, several proven suppliers, a clear procedure for dealing with delays, and an early warning system that signals problems before they turn into a stoppage of supply. Inventory management and demand planning become important, because too small inventories increase the risk of downtime, and too large inventories freeze working capital and reduce liquidity (Nazarova et al.., 2021).

Therefore, the essence of the modern concept is that foreign economic decisions are made taking into account the full chain, where a weak point can arise anywhere, and the response should be systemic, not point-based.A separate feature of modern management is measuring the effectiveness of foreign economic activity through indicators, but not for the sake of reporting, but for the sake of improving decisions. The enterprise should see the real profitability of international operations, taking into account all costs, including logistics, insurance, packaging, certifications, bank commissions, brokerage costs and personnel time costs.

It is also important to monitor the quality of performance, the frequency of complaints, the average payment period, the share of overdue receivables, the stability of delivery terms, as well as the accuracy of planning, when the actual terms and actual costs correspond to the agreed ones. In the modern concept of assessment, the management is built so that it sees cause-and-effect relationships, for example, how changing the terms of payment affects the turnover of funds, or how choosing a different route affects the terms and the risk of damage to the cargo. This allows you to reduce subjectivity and act on the basis of facts, not feelings (Kniaz, 2021). As a result, foreign economic activity ceases to be a sphere where everything depends on one experienced specialist, and becomes a manageable system that can be scaled, trained, and stably replicated in new markets.

The company needs negotiation skills, contractual thinking, financial discipline, understanding of logistics, knowledge of industry requirements and the ability to work with data. It is important to form a culture of

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responsibility for the document, for the deadline, for quality, for obligations, because an international partner often evaluates the company not by beautiful words, but by small regular manifestations of professionalism. In this part, the modern concept is supported by digital solutions, electronic document management and corporate accounting systems, which reduce the likelihood of errors and accelerate coordination, and can also be supplemented by technologies based on artificial intelligence, for example, to analyze large amounts of market information or to assist in preparing management decision options. However, human control and professional judgment remain key, since foreign economic activity is associated with responsibility, legal consequences and reputation. That is why the modern concept of management focuses on creating an organization that can act accurately, transparently, and flexibly, and can sustainably develop an international direction without losing manageability and quality (Le et al.., 2024; Lagodiienko et al.., 2022).

At the operational level, foreign trade management means managing processes that ensure the execution of a contract without disruptions and losses. This includes work on finding and pre-selecting counterparties, checking their reliability, agreeing on technical specifications and commercial terms, preparing a draft contract, agreeing on delivery terms, forming a package of documents, planning production to order, quality control before shipment, organizing transport and warehousing, customs clearance, interacting with banks, and controlling payment receipt. It also includes managing communication with a partner, when the company does not «disappear» after signing a contract, but regularly clarifies the status of the order, confirms dates, quickly responds to requests for documents, and transparently resolves problem situations.

Operational management requires clear regulations and standards, because people can change, and the quality of performance must remain stable. It is important that the enterprise has document templates, a list of control points, rules for checking marking and packaging, instructions for interaction with carriers, as well as certain levels of decision approval, for example, who can agree on a discount and who can agree on a deferral. In this sense, foreign economic activity management is the organization of repeatability and discipline, which reduces the dependence of the result on chance and the human factor. A separate management unit is financial and legal support, because foreign economic activity is always associated with currency transactions, international payments, contract risks and regulatory

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requirements.

Finance here includes calculating the real profitability of the transaction taking into account «hidden» costs, managing receivables, choosing payment terms, advance payments, partial prepayments, financial guarantees, documentary instruments, as well as cash flow planning so that the enterprise does not find itself in a situation where a profitable contract creates a temporary shortage of funds. The legal aspect includes the correct execution of contracts, determination of the parties' responsibilities, dispute resolution procedures, quality and acceptance requirements, the procedure for submitting claims, sanctions and restrictive norms, as well as compliance with customs and tax regulations. Management means not only knowing these rules, but also incorporating them into internal procedures so that the enterprise acts correctly automatically, and does not "remember" the requirements at the last moment. In international agreements, the risk of non-payment is especially important, so management includes checking the counterparty, limits, insurance, alternative settlement instruments, and monitoring overdue payments. Equally important is currency risk, where exchange rate fluctuations can turn the planned profit into a loss, so the enterprise needs a pricing policy, which currency to give preference to, how often to review the price, and what restrictions to introduce for risky contracts. As a result, the financial and legal block is a «protective frame» of foreign economic activity that allows the enterprise to grow without critical failures.

In today's world, managing foreign trade also means developing a system of competencies and supporting decisions with data so that the company can consistently learn from its own experience and become stronger with each contract. International work requires specialists who are able to negotiate, understand the logic of contracts, work with logistics and document management, and can quickly navigate the requirements of different markets. But even the best specialists need a system, so management includes training, internal instructions, knowledge base accumulation, communication standards, as well as tools for control and analysis. Data is needed to see which markets are profitable, which customers create the most value, where delays occur, which carriers work better, which payment terms are safer, and at what stages typical errors occur. This can be done using corporate information systems, electronic document management and analytical panels, as well as artificial intelligence-based technologies, which sometimes help to process information about markets faster, structure documents, or support risk

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analysis. However, the essence of management is not in the tools, but in the fact that the enterprise creates a managed model of international activity, where people, processes and control work together. Then foreign economic activity becomes not a one-time success, but a stable function that brings growth, diversification, stronger competitive positions and higher business stability.

Once foreign economic activity is treated as an end to end system with defined roles, documents, control points, and risk safeguards, the next question concerns managerial capability. Specifically, the enterprise must ensure visibility, traceability, and timely feedback across multiple functions and external partners. In practice, these requirements cannot be met sustainably through manual coordination. Therefore, digitalization becomes not only a technological improvement but also the infrastructure of evaluability, because it generates comparable data and supports continuous monitoring.

3. The impact of digitalization on the foreign economic activity management system. Digitalization significantly changes the management system of the enterprise's foreign economic activity, because it transfers key operations from the mode of manual coordination to the mode of managed, transparent and traceable processes. If previously most of the work was based on the experience of individual employees, telephone agreements, emails and sets of files stored in different places, then digital solutions allow you to collect data into a single logic, where each transaction has its own route, statuses, responsible persons, control points and change history. In foreign economic activity, this is especially important, since international operations consist of many stages performed by different departments and counterparties, and any delay or error in the document can create a chain reaction of costs. Digitalization affects not only speed, it affects manageability, because management gets the opportunity to see the real state of the contract portfolio, the level of readiness of orders, expected shipment dates, risk points in logistics and the status of settlements. As a result, the management system moves from reacting to problems to preventing them, because signals about deviations appear earlier, and decisions can be made based on specific data, and not just on assumptions. In foreign economic activity, a document is not a formality, but a tool that opens or blocks the movement of goods, money and responsibility. Digital approaches to document management help reduce the number of errors in invoices, specifications, packing lists, transport

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documents and certificates, because data is taken from a single source, and checks are configured as mandatory rules. When an enterprise uses electronic templates, field filling control, automatic approvals and electronic signatures, it reduces the risk that a critically important detail will be missed due to the human factor or haste. In addition, the speed of approvals between departments increases, because digital approval routes provide transparency as to who is delaying a document and at what stage, and why. For management, this means increased discipline and transparency, as well as the formation of an evidence base in case of disputes with a counterparty, carrier or regulatory authorities. It is also important that digitalization facilitates internal audits, because the history of changes, versions, approvals and additions is not lost, and the manager can quickly assess whether internal policies regarding payment terms, insurance, carrier selection and other critical transaction parameters have been complied with (Table 1.18).

Digital platforms for planning transportation, tracking transport status, warehouse management and interaction with brokers allow the company to more accurately predict deadlines, respond faster to delays and better coordinate production with real delivery capabilities. In international operations, this is critical, because a delay at one stage can turn into downtime, fines, additional storage costs or a breach of obligations to the buyer. When a company has a digital picture of the movement of batches, it can warn the customer in advance, adjust the shipment schedule, order an alternative route or change warehouse planning without bringing the situation to a crisis. For the management system, this means that decisions become faster and more accurate, and responsibility becomes clearer, because it is visible at what stage the problem arose and what actions were taken. It is worth emphasizing separately that the digitalization of logistics supports cost management, because the company can compare actual costs by routes, carriers and types of cargo, and use this data to optimize delivery terms, choose packaging, consolidate batches or change the composition of transportation costs in the contract price.

Artificial intelligence technologies help make management decisions primarily because they quickly transform disparate enterprise data into a clear picture of the situation, which shows cause-and-effect relationships, trends and early signals of problems.

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Table 1.18. Digitalization of the foreign economic activity management system

Digitalization dimension	Extended explanation
Integrated data environment and management visibility	Digitalization connects previously fragmented information flows from sales, procurement, production, logistics, finance, and legal functions into a single data environment. This creates a reliable “single source of truth” for contracts, product specifications, shipment schedules, costs, and payment terms. Management gains real time visibility into the pipeline of international deals, current bottlenecks, and critical deadlines, which supports faster escalation and better prioritization. Such visibility also improves accountability because every stage has an owner, a timestamp, and a trackable status, reducing the reliance on informal communication and personal memory
Digital document flow, standardization, and compliance assurance	International operations depend on documentary accuracy, including invoices, packing lists, certificates, transport documents, and customs declarations. Digital document flows reduce errors by using standardized templates, mandatory fields, automated checks, and version control, so critical data is not lost, duplicated, or changed without trace. Approval workflows accelerate coordination between departments and ensure that legal, financial, and operational requirements are reviewed before shipment. Compliance improves because the system can enforce rule based controls, for example confirming that required certificates are attached, that Incoterms and payment terms match internal policies, and that labeling and origin statements are consistent
Logistics digitalization and end to end traceability of shipments	Digital logistics tools support planning, execution, and monitoring of international transportation. They enable tracking of shipment milestones, proactive notifications about delays, and coordination with carriers, warehouses, and customs brokers. Traceability improves decision making because the firm can link physical movement with contractual obligations, production readiness, and customer communication. Digitalization also supports cost management by capturing freight, handling, and insurance expenses and associating them with specific orders, routes, and carriers
Financial digitalization, cash flow control, and risk monitoring	Digitalization strengthens financial management by synchronizing contract data with invoicing, receivables tracking, and banking operations. This allows more accurate cash flow forecasting and early detection of payment delays, discrepancies between contract terms and actual settlements, and liquidity pressure caused by long logistics cycles. Currency exposure can be monitored more systematically because the enterprise can track expected foreign currency inflows and outflows and simulate how exchange rate changes influence margins

Sources: formed by the authors

In real work, a manager often deals with a large number of sources, sales, purchasing, production, logistics, finance, customer complaints, contract fulfillment, warehouse loading, cash flow. A person can review some of the indicators, but it is difficult for him to simultaneously take into account dozens of factors and their interdependence, especially when the information is updated daily. Artificial intelligence technologies can combine data from different systems, clean it of duplications, errors and omissions, group it by products, markets, customers, responsible managers and sales channels, and

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then suggest where there is a deviation from the norm. For example, they may discover that an increase in complaints coincided with a change in packaging supplier, or that a drop in margins is due not to discounts but to increased shipping costs through a different route.

As a result, the management decision becomes less intuitive and more justified, because the manager sees not only the fact of the problem, but also a possible source, and also receives a list of response options with an explanation of what exactly these options affect. AI-based technologies are able to build forecasts of demand, sales, delivery times, inventory needs and production loads based on history, seasonality, prices, promotional activity, order dynamics and customer behavior. They can also model scenarios of what will happen if the exchange rate changes, transportation tariffs increase, additional certification requirements appear, or the carrier delays delivery.

For a manager, this is a very practical tool, because the decision is then made together with an understanding of the consequences, for example, how the profitability of the contract will change, whether there will be enough working capital, whether there will be a shortage of materials, and what deadlines are realistic. It is also important that such approaches strengthen the discipline of implementing decisions, since control parameters are immediately formed that show whether the company is moving according to the chosen scenario or whether the plan needs to be adjusted. That is, technologies based on artificial intelligence help not only choose a direction but also accompany the implementation of the decision through regular forecast updates, comparison of the plan and the fact, and tips where the risk of disruption arises.

Artificial intelligence-based technologies can automate routine actions, such as checking the completeness of documents, comparing invoices with the terms of the contract, checking the correctness of details, searching for discrepancies between the specification and the actual shipment, as well as preparing standard messages to the partner regarding the status of the order. In the implementation of management decisions, this has two effects: first, the time between decision and action is reduced, and second, the number of errors that usually appear in small things but are costly when the cargo is already at the border or when payment is delayed due to an incorrectly drawn up document is reduced. Such technologies can also help dispatching, when the system suggests the optimal sequence of shipments, suggests which batches are better to consolidate, where there is a risk of warehouse overload, and

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which orders need to be accelerated so as not to violate the promised deadline.

As a result, management decisions about priorities, such as «first fulfill an order with a high late payment penalty» or «transfer some volumes to another route» are translated into concrete actions faster, because the system suggests what exactly needs to be changed in the production schedule, delivery plan, and resources. They are able to assess the risk of non-payment based on payment history, counterparty behavior, frequency of requests for deferrals, unusual changes in orders, and indirect signs that a deal may be problematic. This is not a replacement for security or a financier, but it is a useful early warning tool that signals that the counterparty should reduce the limit, tighten payment terms, or require additional guarantees. AI-based technologies also help to more accurately calculate the real profitability of contracts when logistics, insurance, certifications, bank commissions, packaging costs, document processing costs, and personnel time are included in the calculation. On this basis, the manager can make decisions about the minimum acceptable price, which delivery terms are more profitable, and which customer segments give the best result in the long term. The financial unit also benefits from implementing decisions, because the system can automatically track payment terms, create tasks for managers, prepare arguments for negotiations, and show how currency exchange rate changes will affect the expected result. This makes financial discipline more stable and management decisions less risky.

AI-based technologies can help create internal prompts for new employees, quickly find the necessary rules, templates, instructions, document requirements and common mistakes, as well as summarize the experience of previous agreements. In foreign economic activity, this is very valuable, because many problems are repeated, but in different forms, and the company either learns from them systematically or pays for them again and again. Such technologies can help analyze correspondence with customers, highlight frequent reasons for dissatisfaction, offer clearer wording of answers and maintain service standards. At the same time, it is important to correctly understand the boundaries, AI-based technologies are a support tool, and responsibility for decisions, for ethics, for compliance with legal requirements and for the final result remains with the manager and team.

The best effect occurs when an enterprise combines these technologies with clear processes, defined roles, quality data, and a culture of discipline, then decisions are made faster, executed more accurately, and adjustments are

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made before the problem becomes critical (Figure 1.7).

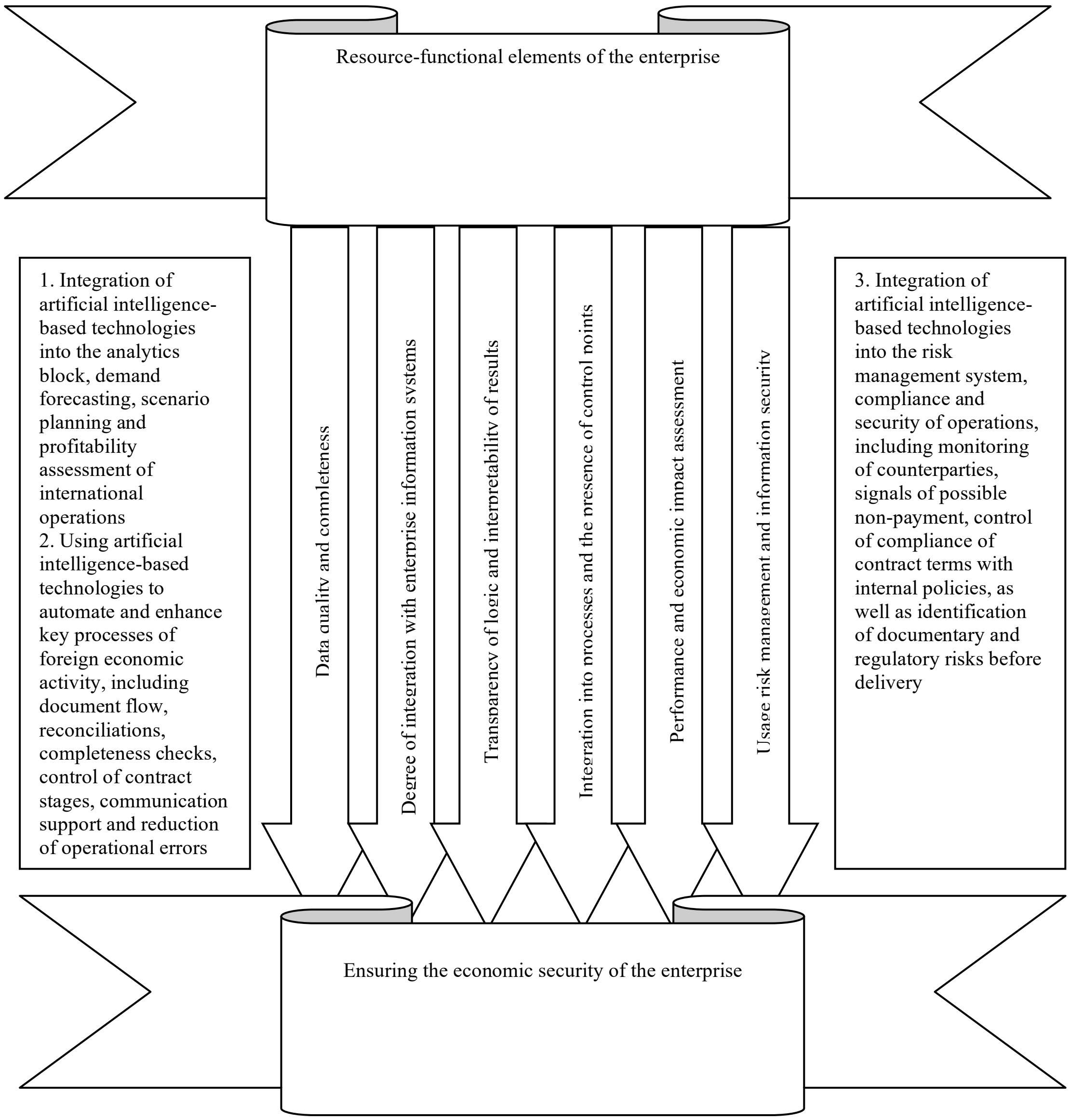

Figure. 1.7. Priority schematic representation of the integration of technologies based on artificial intelligence into the foreign economic activity management system

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Digitalization changes the evaluation of foreign economic activity management in two fundamental ways. First, it converts many qualitative

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managerial practices into measurable events, such as approval times, document error rates, deviation frequencies, logistics milestone delays, and settlement discipline. Second, it enables a closed feedback loop where indicators are updated regularly, and corrective actions can be tracked to outcomes. Accordingly, the evaluation system should be built on digital trace data, standardized definitions of indicators, and a reporting cycle aligned with decision making. The next section should formalize the indicator set, scoring logic, data sources, and governance procedures for using the results in managerial improvement.

4. Methodology for Evaluating the Management of Foreign Economic Activity. The evaluation of foreign economic activity management should be grounded in principles that ensure methodological transparency and managerial usefulness in volatile international environments (Tulchynska et al., 2021). Relevance means that indicators capture the real determinants of performance in cross border operations, including delivery reliability, settlement discipline, compliance stability, and margin resilience (Kniaz, 2021). Comparability requires unified definitions of metrics across products, markets, and counterparties, so that results can be benchmarked and interpreted consistently over time (Rudnichenko et al., 2021). Timeliness is essential because delays in documentation, customs procedures, or logistics quickly translate into financial losses and reputational damage, so monitoring must deliver early warning signals rather than solely retrospective explanations (Viknianska et al., 2021). Traceability implies that each indicator is linked to verifiable data sources and responsible roles, supporting accountability and internal control (Navickas et al., 2016). Risk sensitivity is critical because foreign economic activity increases exposure to currency volatility, regulatory differences, and counterparty default, which can neutralize revenue growth if not managed systematically (Nazarova et al., 2021). Collectively, these principles define evaluation as a governance mechanism that supports decisions and continuous improvement rather than a formal reporting routine (Le et al., 2024).

A logically complete evaluation system should integrate outcome indicators with leading indicators that reflect process quality and risk control, since international success is determined by both results and the repeatability of the workflows that produce them (Kniaz, 2021). A practical architecture includes five indicator blocks. First, results and economic efficiency reflect international revenue, contribution margin per contract, full cost profitability,

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and retention of strategic counterparties, which supports value based competition and long term positioning (Tulchynska et al., 2021). Second, process quality and execution discipline measure on time delivery, contract cycle time from agreement to payment, documentary error rates, rework frequency in customs documentation, and claim rates, because small procedural errors often generate disproportionate losses in international contexts (Viknianska et al., 2021). Third, risk and compliance performance includes overdue receivables, payment default incidents, currency deviations from planned margins, customs and certification noncompliance events, and the coverage of contracts by mitigation instruments such as insurance or guarantees (Navickas et al., 2016; Nazarova et al., 2021). Fourth, resource efficiency captures production capacity utilization linked to foreign contracts, logistics and warehousing costs by route, and demurrage or penalty expenses, reflecting the need to manage the full value chain rather than isolated transactions (Navickas et al., 2016). Fifth, digital maturity assesses the coverage of electronic document flow, integration of ERP, CRM, and logistics systems, the share of transactions with trackable statuses, and the extent of automated controls that prevent noncompliant terms, which strengthens transparency and scalability (Lagodiienko et al., 2022; Le et al., 2024). Such a structure ensures that management is evaluated not only by revenue outcomes but also by operational reliability, resilience, and the capacity to scale (Rudnichenko et al., 2021).

For evaluation to be actionable, indicators should be translated into a composite score through transparent normalization and weighting rules (Kniaz, 2021). A two stage model is appropriate. First, each indicator is normalized to a unified scale, for example 0 to 100, using targets, benchmarks, or historical baselines that reflect the enterprise's market context and strategic ambitions (Rudnichenko et al., 2021). Second, weighted aggregation is applied at block level and then combined into an overall index of foreign economic activity management effectiveness, enabling integrated interpretation across performance dimensions (Tulchynska et al., 2021). Weighting should reflect management levels. Strategic weights prioritize market diversification, partner portfolio stability, margin resilience, and risk posture, because these parameters shape long term sustainability in foreign markets (Nazarova et al., 2021). Tactical weights emphasize pricing accuracy, cost transparency, contract standardization, and resource allocation, as these factors determine controllability and predictable execution (Viknianska et al.,

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2021). Operational weights prioritize delivery performance, document accuracy, settlement discipline, and claims, since these indicators capture reliability and reputational capital in international exchange (Navickas et al., 2016). Weight sets should be reviewed periodically because entry modes, logistics constraints, and regulatory exposure evolve, and static weights can distort managerial signals during structural change (Le et al., 2024).

The credibility of evaluation depends on data governance and the consistency of measurement procedures (Lagodiienko et al., 2022). Core sources typically include ERP systems for cost accounting, production readiness, invoicing, and receivables, CRM systems for pipeline and counterparty histories, and logistics systems such as TMS and WMS for shipment milestones, route performance, and warehouse events (Navickas et al., 2016). Electronic document management provides audit trails for approvals, version control, and completeness checks, which is especially important in foreign economic activity where documentation enables or blocks the movement of goods and payments (Viknianska et al., 2021). Banking data or treasury modules are required for settlement monitoring, exchange rate effects on margins, and liquidity forecasting, particularly when payment terms vary and logistics cycles are prolonged (Nazarova et al., 2021). If integrated systems are not yet available, interim registers can be used, but definitions and verification procedures must be formalized to prevent fragmentation and subjective reporting (Kniaz, 2021). Measurement frequency should align with decision cycles. Operational indicators should be reviewed weekly, tactical indicators monthly, and strategic indicators quarterly, ensuring that evaluation supports timely corrective action and learning (Le et al., 2024).

The evaluation system should operate as a closed loop that links measurement to corrective action, organizational learning, and the stabilization of repeatable procedures (Kniaz, 2021). The cycle begins with dashboard review and deviation detection, where issues are classified by severity and assigned to responsible managers with deadlines and documented action plans (Lagodiienko et al., 2022). Corrective actions should be traceable through digital workflows, making it possible to verify whether process changes were executed and whether they produced the intended operational and financial effects (Le et al., 2024). After action reviews are necessary for recurring failures such as repeated customs delays, systematic document errors, margin erosion on specific routes, or chronic settlement deviations,

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because these patterns usually indicate structural weaknesses in procedures or risk controls (Viknianska et al., 2021; Nazarova et al., 2021).

The outcomes of reviews should be embedded into updated templates, revised approval limits, strengthened counterparty checks, alternative logistics scenarios, and staff training mechanisms, thereby increasing organizational maturity and reliability in international work (Navickas et al., 2016; Tulchynska et al., 2021). Quarterly recalibration of targets and weights is recommended to reflect changes in market conditions, regulatory requirements, and technology adoption, and to preserve the validity of managerial signals (Le et al., 2024). In this model, evaluation becomes an instrument for disciplined governance that reduces losses, strengthens international trust, and supports scalable growth rather than a static summary of past performance (Rudnichenko et al., 2021).

Conclusions. In conclusion, the management of an enterprise's foreign economic activity should be designed as an integrated governance system that links strategic intent with disciplined execution across processes, finance, legal support, logistics, and customer relationship management. Such integrity differentiates sustainable international performance from episodic transactions because it ensures repeatability, transparent allocation of responsibility, and scalability without a proportional rise in operational errors, financial losses, or reputational damage. Effective management therefore encompasses the entire transaction cycle, from market and counterparty selection through specification discipline, quality assurance, shipment coordination, settlement control, claims handling, and the maintenance of long term partnerships.

Digitalization reinforces this managerial architecture by making workflows traceable, measurable, and controllable, thereby shifting decision making from intuition to evidence. Integrated data environments, electronic document flows, and standardized approval routes reduce documentary errors, shorten coordination cycles, and strengthen compliance discipline, which is critical in cross border operations where small inaccuracies can trigger delays, penalties, and partner distrust. As a result, the enterprise gains earlier visibility of deviations, more accurate cost and profitability attribution by contract and route, and higher predictability of cash flows, all of which directly support resilience and competitiveness in international markets.

Artificial intelligence technologies add an analytical layer that improves decision quality under uncertainty by accelerating the processing of

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heterogeneous data, identifying causal patterns, generating risk signals, and supporting forecasting and scenario planning. In implementation, AI-based tools can reduce the workload on personnel through automated checks, reconciliations, and document completeness control, while enhancing precision in logistics milestones, delivery time management, and payment monitoring. At the same time, these technologies should be embedded as decision support mechanisms rather than substitutes for managerial accountability, legal compliance, and professional judgment.

Overall, the chapter substantiates that the synergy of systemic management, digitalization, and AI-enabled decision support forms a tangible managerial advantage. It increases the reliability of foreign economic activity, lowers the cost of errors, strengthens financial stability, and creates organizational capacity for sustained and controlled growth in international markets.

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Chapter 2
Business Transformation in the Context of War and Digitalization

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Section 2.1. Tax Levers Influence on Digital Entrepreneurship Development in Ukraine

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Abstract. *This study analyzes how tax levers shape the development of digital entrepreneurship in Ukraine and how they can support innovation, resilience, and inclusive growth under prolonged external threats. Digital entrepreneurship has become a critical driver of economic adaptation because it relies on intangible assets, scales rapidly, and operates with high geographic flexibility, which makes it a distinctive object of taxation that does not fully fit traditional fiscal frameworks. In crisis-affected and institutionally transforming economies, tax policy functions not only as a revenue tool but also as a governance mechanism that influences entry into entrepreneurship, incentives for formalization, business survival, and the capacity to scale. The aim is to develop a theoretical framework for analyzing the influence of tax levers on the development of digital entrepreneurship in Ukraine, with particular attention to the entry - scaling trade-off, institutional mediation of tax effects, and the constraints imposed by European integration and international tax coordination. The methodology is qualitative and theory-driven, combining structured literature analysis, institutional economic reasoning, and comparative conceptual synthesis across digital entrepreneurship, crisis economics, and international taxation. Conceptual comparisons are used to position Ukraine's approach relative to prevalent European support models. The analysis indicates that tax levers operate through a dual pathway: they can lower barriers to entry and strengthen resilience through simplified regimes, while also shaping incentives for innovation and scaling through targeted instruments and special frameworks. Simplified taxation supports entrepreneurial continuity under crisis conditions, yet it may limit structural upgrading if not complemented by credible scaling mechanisms. Special regimes such as Diia.City can mitigate this trade-off when embedded in stable institutions and supported by high governance capacity. Overall, tax policy is conceptualized as a dynamic instrument that can enable both resilience and structural transformation when strategically sequenced and institutionally anchored.*

Keywords. *digital entrepreneurship; tax levers; taxation policy; institutional quality; entry-scaling trade-off; crisis resilience; digital economy; European integration; Ukraine.*

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1. Theoretical Analysis of Tax Levers Influencing Digital Entrepreneurship Development in Ukraine. Digital entrepreneurship represents a structurally distinct form of economic activity, characterized by the predominance of intangible assets, high scalability, and geographic flexibility of production and labour (Autio et al., 2018; Nambisan, 2017). These features challenge traditional taxation frameworks that are designed around physical presence, fixed capital, and territorially bounded value creation. In digital business models, value is increasingly generated through software, data, intellectual property, and platform-mediated interactions, which complicates tax base allocation and heightens sensitivity to regulatory and fiscal conditions.

In the Ukrainian context, this specificity has been reinforced by prolonged external threats, which have disrupted physical infrastructure and intensified labour mobility. Digital entrepreneurship has functioned as a mechanism of economic continuity, allowing firms and individuals to sustain income generation under conditions of uncertainty and displacement. Consequently, tax policy toward digital entrepreneurship must be analysed not only through efficiency or revenue lenses but also through its capacity to support resilience and adaptive behaviour (OECD, 2024).

In digital economies, tax levers operate primarily through behavioural and institutional channels rather than through static price effects. From an institutional economics perspective, taxation shapes entrepreneurial decisions by influencing compliance costs, perceived fairness, predictability, and trust in state institutions (North, 1990; Williamson, 2000). For digital entrepreneurs - who can often reconfigure legal form, contractual arrangements, or tax residency - these institutional signals are particularly salient.

Three interrelated mechanisms are theoretically central. First, the entry - formalization mechanism emphasizes the role of simplified taxation in lowering compliance costs and encouraging formal economic participation. Where institutional trust is limited and administrative complexity is high, simplified regimes act as substitutes for weak institutional capacity, facilitating formalization rather than tax avoidance (Djankov et al., 2010).

Second, the scaling and investment mechanism highlights the limits of entry-oriented tax systems. As firms mature, their primary constraints shift toward access to capital, organizational growth, and innovation commercialization. Tax regimes that remain optimized for micro-entrepreneurship may inadvertently discourage corporatization, reinvestment,

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and long-term planning, leading to structural fragmentation of the digital sector (Acs et al., 2018).

Third, under crisis conditions, taxation affects digital entrepreneurship through a resilience mechanism. Temporary reliefs, deferred payments, and simplified procedures reduce liquidity pressure and lower exit probabilities. In prolonged crises, such instruments function as automatic stabilizers, supporting survival rather than expansion (OECD, 2022).

The Ukrainian case illustrates a fundamental entry - scaling trade-off inherent in digital taxation design. Simplified tax regimes have significantly reduced barriers to entry and enabled rapid expansion of freelance and contract-based digital work. This has supported employment, export earnings, and territorial diffusion of digital activity, particularly under crisis conditions.

However, theoretical and comparative literature suggests that prolonged reliance on simplified taxation may constrain firm growth and capital accumulation (European Commission, 2021). Entry-friendly regimes prioritize flexibility and income stabilization, while scaling-oriented regimes emphasize predictability, investment incentives, and integration into global value chains. The trade-off arises because tax systems optimized for one margin of entrepreneurial behavior (entry) are not necessarily optimal for another (scaling).

This tension motivates the concept of a policy ladder, whereby simplified taxation supports early-stage activity, while clearly defined transition pathways guide firms toward corporate and innovation-oriented tax regimes as they grow. Without such sequencing, digital ecosystems risk becoming locked into low-capital, high-fragmentation equilibria.

Diia.City represents an institutional attempt to mitigate the entry - scaling trade-off by introducing a special legal and tax regime for the digital sector. From a theoretical standpoint, it can be interpreted as a hybrid governance instrument combining fiscal incentives, labor market flexibility, and regulatory predictability.

Unlike simplified taxation, Diia.City is designed to support corporatization, reinvestment, and engagement with global investors. Its effectiveness, however, depends not solely on tax parameters but on institutional credibility. Institutional theory emphasizes that entrepreneurs respond not only to current incentives but also to expectations about policy stability and enforcement consistency (Rodrik, 2008). In crisis environments, perceived risks of regulatory reversal or selective enforcement may reduce the

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attractiveness of more visible and regulated regimes, even if nominal incentives are favorable.

Thus, Diia.City's success as a scaling mechanism depends on its integration into a broader framework of legal stability, transparent administration, and long-term policy commitment.

A central theoretical conclusion is that tax levers do not operate independently of institutional context. Governance capacity, administrative quality, and rule predictability mediate the effectiveness of fiscal incentives (North, 1990; Acemoglu & Robinson, 2012). In environments with weak institutions, generous tax incentives may fail to induce investment or scaling, while in stronger institutional settings even moderate incentives can be effective.

For Ukraine, this implies that tax policy for digital entrepreneurship must be embedded within broader institutional reforms, including digital governance, judicial reliability, and transparent tax administration. Without such complements, tax levers risk reinforcing short-termism rather than fostering structural transformation.

Tax policy design for digital entrepreneurship is increasingly shaped by international coordination and European integration dynamics. OECD/G20 initiatives on base erosion and profit shifting, particularly the global minimum corporate tax (Pillar Two), constrain the scope for aggressive corporate tax competition (OECD, 2023). While most Ukrainian digital firms currently fall below the size thresholds of these rules, ecosystem anchors and future growth trajectories will increasingly operate within this regulatory environment.

In the European Union, digital entrepreneurship policy emphasizes scaling, innovation commercialization, and intellectual property development through corporate taxation, R&D credits, and innovation box regimes (European Commission, 2022). This creates a comparative benchmark for Ukrainian entrepreneurs and investors. Theoretically, abrupt convergence toward EU-style taxation could undermine Ukraine's adaptive advantages, while gradual, sequenced alignment allows preservation of entry flexibility alongside strengthening of scaling incentives.

Digital entrepreneurship has emerged as a key driver of economic resilience, innovation, and structural transformation in Ukraine, particularly under conditions of prolonged external threats. The rapid expansion of digital platforms, IT services, fintech solutions, and online business models has enabled economic actors to maintain activity despite physical infrastructure

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disruption, security risks, and population displacement. In this context, taxation policy plays a critical role in shaping the incentives, sustainability, and spatial distribution of digital entrepreneurial activity.

Tax levers understood as targeted tax instruments, regimes, incentives, and administrative mechanisms and constitute one of the most flexible and powerful tools of state regulation of digital entrepreneurship. Unlike direct subsidies or industrial policy instruments, tax levers operate through incentive structures that influence business formalization, investment behavior, innovation intensity, and market entry. In crisis-affected economies such as Ukraine, the design and implementation of tax policy becomes especially consequential, as excessive fiscal pressure may suppress entrepreneurial activity, while poorly targeted incentives may exacerbate inequality or erode the tax base.

Digital entrepreneurship refers to entrepreneurial activity in which digital technologies constitute a core element of value creation, delivery, or capture. This includes software development, IT outsourcing, platform-based services, e-commerce, digital finance, and data-driven business models. Unlike traditional entrepreneurship, digital entrepreneurship is characterized by high scalability, lower marginal costs, and reduced dependence on physical location.

In the Ukrainian context, digital entrepreneurship has demonstrated exceptional adaptability, with the IT sector and related digital services maintaining export revenues and employment even during periods of intense external pressure. This resilience underscores the importance of an enabling regulatory and fiscal environment.

Tax levers encompass a set of policy instruments through which the state influences economic behavior by adjusting tax rates, bases, exemptions, special regimes, and administrative procedures. From a theoretical perspective, tax levers affect entrepreneurship through several channels (Figure 2.1).

For digital entrepreneurs, whose assets are often intangible and mobile, taxation regimes significantly influence decisions regarding location, legal form, and scale of operations.

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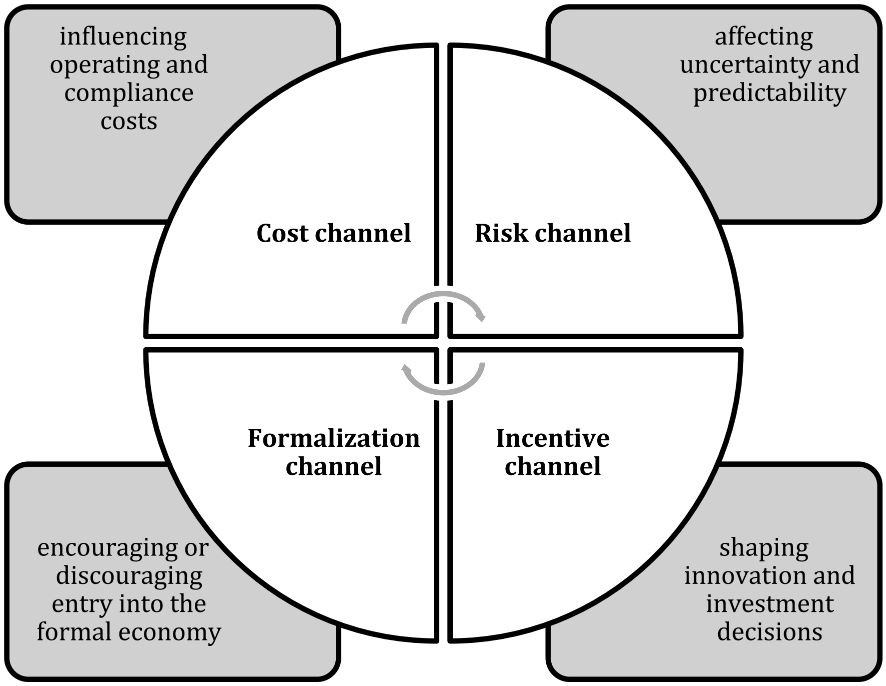

Figure 2.1. Tax Levers as Instruments of Economic Regulation
Source: created by the author

2. Digital Entrepreneurship and Tax Levers. Digital entrepreneurship differs from traditional entrepreneurial activity along several structural dimensions that are directly relevant for taxation:

1. Intangibility of assets, which complicates tax base identification and valuation;
2. High scalability, where marginal revenues increase faster than marginal costs;
3. Geographic flexibility, reducing dependence on local infrastructure;
4. Human-capital intensity, making taxation of labor and income particularly sensitive.

In Ukraine, these features are especially pronounced in IT services, software development, platform-based activities, and digital freelancing. The prevalence of individual entrepreneurs (FOPs) in the digital sector reflects a rational response to tax and regulatory structures that favor simplified compliance over corporate formalization.

From a theoretical perspective, digital entrepreneurship challenges classical tax design principles that rely on stable production locations, tangible

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assets, and clear jurisdictional boundaries. As a result, tax levers in the digital economy operate primarily through behavioral and institutional channels, influencing how entrepreneurs structure their activities rather than merely how much tax they pay.

Tax levers affect digital entrepreneurship through a set of interrelated mechanisms that extend beyond nominal tax rates.

Taxation directly influences the liquidity position of digital entrepreneurs, particularly small-scale and early-stage ventures. Simplified taxation regimes reduce compliance costs and free up resources for investment in skills, technology, and market expansion. Under prolonged external threats, liquidity becomes a critical determinant of survival, amplifying the importance of tax relief and deferral instruments.

Entrepreneurial activity in crisis conditions is characterized by elevated uncertainty. Tax policy that is unstable, ambiguous, or inconsistently enforced increases perceived risk and discourages long-term planning. Conversely, predictable and transparent tax levers reduce uncertainty premiums and support entrepreneurial commitment.

Tax regimes influence the decision to operate formally or informally. In Ukraine, the widespread use of simplified taxation among digital entrepreneurs reflects not only cost considerations but also institutional trust deficits. When tax administration is perceived as complex or arbitrary, simplified regimes function as institutional substitutes that lower interaction costs with the state.

Building on the conceptual and institutional analysis of tax levers as mechanisms shaping digital entrepreneurship under prolonged external threats, this chapter advances a set of testable hypotheses that formalize the causal logic between taxation, entrepreneurial behavior, and resilience outcomes.

First, simplified and predictable tax regimes reduce entry barriers and compliance costs for digital entrepreneurs, particularly in sectors characterized by intangible assets and remote work. Accordingly, it is hypothesized that lower effective tax burden and simplified tax administration are positively associated with the density of digital entrepreneurs (H1).

Second, while simplified taxation supports entry and survival, it may constrain firm growth, investment, and integration into international value chains. Therefore, it is hypothesized that simplified tax regimes exert a positive effect on the number of digital entrepreneurs but a weaker or negative

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effect on firm scaling and capital accumulation (H2).

Third, special tax - legal regimes targeted at the digital sector (such as Diia.City in Ukraine or IP box and startup regimes in EU member states) are designed to encourage investment, innovation, and corporate formalization. Hence, the presence of targeted digital tax regimes is positively associated with higher value-added, export intensity, and innovation activity in the digital sector (H3).

Fourth, under crisis conditions, tax levers influence not only growth but also survival. It is therefore hypothesized that temporary tax relief measures and deferred tax obligations improve the resilience of digital entrepreneurship during periods of external shocks (H4).

Fifth, the effectiveness of tax levers is mediated by institutional quality. Thus, the positive impact of favorable tax regimes on digital entrepreneurship is stronger in territories with higher governance capacity and regulatory predictability (H5).

Finally, from a comparative perspective, it is hypothesized that Ukraine's reliance on simplified taxation generates higher entry and flexibility than EU digital tax regimes, but lower levels of firm scaling and investment, reflecting different stages of digital ecosystem maturity (H6).

3. Simplified Taxation Regime: Enabler and Constraint. The simplified taxation system has been a foundational driver of Ukraine's digital entrepreneurship growth. By offering low effective tax rates and minimal administrative burden, it enabled rapid formalization of freelance and contract-based digital work, supporting export-oriented IT services and remote employment.

Empirically, this regime has contributed to:
- high rates of business registration among digital workers;
- resilience of digital exports under crisis conditions;
- diffusion of digital entrepreneurship beyond major metropolitan centers.

However, reliance on simplified taxation creates structural distortions. It discourages scaling into corporate forms, limits access to external investment and may conflict with international tax norms. Moreover, prolonged dependence on simplified regimes risks institutional lock-in, where innovation ecosystems remain fragmented and undercapitalized.

From a theoretical standpoint, simplified taxation functions as a short- to medium-term resilience tool, but not as a comprehensive development instrument for a mature digital economy.

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Diia.City represents a deliberate attempt to recalibrate tax levers to support higher-value digital entrepreneurship. Its design reflects a shift from individual-based taxation toward corporate and investment-oriented models, combining favorable tax treatment with regulatory predictability.

Analytically, Diia.City can be interpreted as an effort to:

- internalize innovation rents within the national economy;
- encourage capital accumulation and reinvestment;
- align Ukraine's digital sector with global value chains.

The effectiveness of Diia.City depends critically on institutional trust and legal stability. In crisis conditions, entrepreneurs may be reluctant to transition into more visible and regulated regimes without strong guarantees against regulatory reversal. This highlights the interdependence between tax levers and broader governance quality.

Under prolonged external threats, tax policy influences not only growth trajectories but survival probabilities. Temporary tax reliefs, deferred payments, and simplified reporting act as automatic stabilizers, reducing liquidity stress and preserving entrepreneurial ecosystems.

Digital entrepreneurs' mobility amplifies the consequences of tax policy missteps. Excessive fiscal pressure or regulatory unpredictability increases the risk of capital and talent relocation, undermining national recovery potential.

Tax policy interacts with digitalization to shape territorial development. Simplified regimes enable digital entrepreneurship in peripheral regions by lowering entry barriers, while corporate-focused regimes tend to concentrate activity in urban centers with stronger institutional infrastructure.

For Ukraine, this creates a policy trade-off between:

- spatial inclusiveness of digital entrepreneurship; and
- structural upgrading toward capital-intensive digital firms.

Effective tax strategy must balance these objectives to avoid reinforcing regional disparities.

Ukraine's tax policy for digital entrepreneurship operates within an increasingly constrained international environment shaped by OECD and EU initiatives on digital taxation and base erosion. Maintaining competitiveness while aligning with international standards requires careful calibration of tax levers and gradual institutional convergence.

A deep analytical synthesis suggests that tax levers should be designed as part of an adaptive governance framework, rather than as isolated incentives. Key priorities include:

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- preserving simplicity for early-stage digital entrepreneurs;
- creating credible pathways for scaling and investment;
- integrating tax policy with digital governance tools;
- ensuring institutional predictability and trust;
- aligning tax incentives with resilience and reconstruction goals.

From a formal perspective, digital entrepreneurial activity can be modeled as a function of tax incentives, institutional quality, and crisis intensity. Let digital entrepreneurship development in territory i at time t be denoted as DE_{it}, measured through indicators such as the number of digital entrepreneurs, digital startups, or digital sector value added.

The baseline analytical model can be expressed as:

$$DE_{it} = \alpha + \beta_1 TAX_{it} + \beta_2 INST_{it} + \beta_3 SHOCK_{it} + \beta_4 X_{it} + \varepsilon_{it} \quad (2.1)$$

where: TAX_{it} represents tax levers (effective tax rates, simplified regimes, special digital tax regimes); $INST_{it}$ captures institutional quality (tax administration efficiency, regulatory predictability); $SHOCK_{it}$ reflects external threat intensity (military activity, displacement, infrastructure damage); X_{it} is a vector of control variables (human capital, digital infrastructure, market size).

To capture the conditional role of institutions, an interaction specification is introduced:

$$DE_{it} = \alpha + \beta_1 TAX_{it} + \beta_2 INST_{it} + \beta_3 (TAX_{it} \times INST_{it}) + \beta_4 SHOCK_{it} + \varepsilon_{it} \quad (2.2)$$

A positive β_3 would confirm hypothesis H5, indicating that tax levers are more effective in environments with stronger institutional capacity.

To operationalize the model, the following indicator groups are proposed (Table 2.1).

At the regional level in Ukraine, these indicators can be derived from national statistical sources, administrative tax data, and international assessments. For the EU comparative analysis, harmonized datasets (Eurostat, OECD, World Bank) allow cross-country benchmarking.

Empirical testing may employ panel-data regression techniques at the regional (Ukraine) and country (EU comparison) levels. Fixed-effects models control for unobserved heterogeneity, while difference-in-differences approaches can be used to evaluate the introduction of special tax regimes (e.g., Diia.City).

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Table 2.1. Indicators framework

Digital entrepreneurship indicators	Tax lever indicators include:
• number of registered digital individual entrepreneurs (IT, software, digital services); • number of digital startups or firms; • digital sector value added and export revenues.	• effective tax burden on digital entrepreneurs; • share of digital entrepreneurs using simplified tax regimes; • participation in special digital regimes (e.g., Diia.City).
Institutional indicators include:	**Crisis and resilience indicators include:**
• tax compliance costs and time; • stability of tax legislation; • governance and rule-of-law indices.	• intensity of external shocks (damage indices, displacement); • survival rate of digital firms during crisis periods.

Source: created by the author

For example, the impact of Diia.City can be assessed as:

$$DE_{it} = \alpha + \delta(POST_t \times TREATED_i) + \beta X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (2.3)$$

where $POST_t$ *indicates the post-introduction period and* $TREATED_i$ *identifies eligible digital firms.*

4. Numerical simulation and scenario analysis. To complement the institutional analysis, a stylized numerical simulation is introduced to illustrate how alternative tax-lever configurations can shift incentives for (a) entry/formalization, (b) scaling/corporatization, and (c) resilience of digital entrepreneurship under prolonged external threats. The simulation does not claim to forecast exact outcomes; rather, it clarifies mechanisms and produces directional, testable implications for empirical work.

The simulation operationalizes two representative agents:

– Type A (micro digital entrepreneur / freelancer) - typical for IT services contracting, platform work, micro-e-commerce.
– Type B (scaling digital firm / startup) - intends to reinvest, hire, and attract investment.

○ The simulation compares three stylized policy scenarios:

– S0: “Entry-first” (status quo logic) - simplified taxation dominates; scaling incentives are weaker.
– S1: “Fast EU convergence” - simplified regime is tightened; higher effective burden and compliance; stronger corporate/R&D tools but higher

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entry friction.

– S2: "Policy ladder" - keeps low-friction entry while strengthening predictable pathways for scaling (e.g., through special regimes and innovation incentives).

For Type A, assume annual revenue $R = €60{,}000$, operating costs $C = €20{,}000$, so operating surplus $R - C = €40{,}000$. We approximate an effective tax burden ETB_A as taxes + mandatory contributions divided by revenue:

$$ETB_A = \frac{\text{Taxes+Mandatory contributions}}{R} \qquad (2.4)$$

For Type B, assume annual profit before tax $\Pi = €200{,}000$, and a distribution ratio $d \in [0,1]$(share of profit distributed rather than reinvested). Under an "exit-capital/distribution" model, the tax burden depends on distributions:

$$Tax_B^{dist} = \tau_d \cdot (d\Pi) \qquad (2.5)$$

This logic aligns with "tax-on-distribution" systems used in some jurisdictions (e.g., Estonia taxes distributed profits) and is also comparable to the Diia.City option of a special regime with 9% on certain payments rather than standard profit taxation.

Table 2.2. Stylized parameterization of scenarios (illustrative)

Scenario	Entry/friction (compliance)	Type A effective burden ETB_A	Type B tax design	Reinvestment incentive
S0 Entry-first	Low	8%	Standard profit tax logic dominates	Medium
S1 Fast EU convergence	High	18%	Greater reliance on corporate taxation; targeted R&D tools	Medium - High (for firms), Low (for entrants)
S2 Policy ladder	Medium	10%	Mix: low-friction entry + scaling regime + innovation incentives	High

Source: created by the author

- S0 is favorable for mass entry and survival but risks "lock-in" into micro-forms (limited corporatization).
- S1 improves formal corporate investment incentives but can suppress

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entry, especially during crisis.

- S2 balances both: entry remains viable while scaling becomes institutionally and fiscally attractive.

To translate burdens into behavioral responses, define two reduced-form indices:

Entry/Formalization propensity (Type A):

$$Entry_A = \exp\left(-\alpha \cdot ETB_A - \beta \cdot Comp\right) \tag{2.6}$$

where $Comp$is a compliance-friction score (1=low, 3=high). Choose $\alpha = 8$, $\beta = 0.35$for illustration.

Scaling propensity (Type B):

$$Scale_B = \exp\left(\gamma \cdot (NetRet)\right) \tag{2.7}$$

where $NetRet$is the post-tax retained resources for reinvestment (normalized), and $\gamma > 0$.

Table 2.3. Simulation results (relative indices; S0 = 1.00 baseline)

Scenario	$Entry_A$(relative)	$Scale_B$(relative)	Implication for structure
S0 Entry-first	1.00	1.00	Many entrants; slower scaling
S1 Fast EU convergence	0.46	1.18	Fewer entrants; more scaling among survivors
S2 Policy ladder	0.83	1.29	Strong entry + strongest scaling

Source: created by the author

Under prolonged external threats, policies that sharply increase entry friction (S1) can reduce the number of formal digital entrepreneurs precisely when the economy needs rapid adaptation and income continuity. A ladder approach (S2) preserves entry while strengthening reinvestment and corporatization incentives, aligning with the chapter's argument that tax levers should support **both resilience and structural upgrading**.

To incorporate prolonged threats, add a shock term $SHOCK_t$that reduces revenues and increases uncertainty. Suppose in a shock year revenues drop by 20% for Type A and 15% for Type B. Resilience is operationalized as the probability of continuing operation:

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$$Survival = 1\{Cashflow_{post-tax} > 0\} \quad (2.8)$$

The S0 and S2 yield higher survival for Type A due to lower fixed burden and friction; S2 yields better survival for Type B due to higher post-tax retention for reinvestment and liquidity buffers.

5. Policy implications: comparison of Ukraine and selected EU states. The table 2.4 compares core tax levers relevant to digital entrepreneurship (entry regime, corporate taxation logic, R&D/IP incentives) and highlights policy intent and trade-offs.

Table 2.4 shows that tax policy for digital entrepreneurship tends to separate into two complementary logics: entry facilitation through simplified regimes and scaling support through corporate taxation and innovation incentives. Ukraine is relatively strong on entry and flexibility, especially through simplified forms and the Diia.City experiment, yet its key strategic challenge is to create a predictable scaling corridor that motivates formal growth without locking founders into micro-regimes. Estonia demonstrates how reinvestment-oriented corporate taxation can support organic scaling, while Ireland and the Netherlands illustrate how targeted innovation instruments can attract R&D activity and monetize intellectual property within the tax system. Poland, in turn, represents an innovation-relief model embedded in a standard PIT/CIT framework, showing that scaling support can be built through layered incentives rather than through a single digital-specific regime. Taken together, the comparison suggests that the most resilient tax architecture for digital entrepreneurship combines low-friction entry with credible, rules-based pathways for reinvestment, innovation commercialization, and transition to scale.

From a comparative standpoint, Ukraine's tax model for digital entrepreneurship differs structurally from those prevailing in the European Union. EU countries typically emphasize:

- corporate-based digital entrepreneurship;
- R&D tax credits and IP box regimes;
- harmonization with OECD BEPS and digital taxation initiatives.

In contrast, Ukraine's model relies heavily on:

- simplified taxation for individual entrepreneurs;
- low entry barriers and administrative simplicity;
- high flexibility under crisis conditions.

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Table 2.4. Tax policy levers for digital entrepreneurship: Ukraine and selected EU comparators

Country	Entry-friendly regime (self-employed / micro)	Corporate tax logic relevant for scaling	Innovation incentives relevant to digital firms	Strategic implication for digital entrepreneurship
Ukraine	Strong reliance on simplified forms (widely used by digital workers); plus Diia.City special legal/tax regime for IT	Diia.City offers choice between standard corporate regime and special taxation on certain payments; Diia.City payroll taxation includes preferential treatment for employees/gig contractors in the regime	Diia.City aims to support investment-oriented digital companies (institutional experiment)	High entry and flexibility; challenge is building a credible “scaling corridor” and avoiding lock-in to micro-forms
Estonia	Digital public infrastructure and streamlined administration (relevant for founders); not a special “digital-only” tax, but simplicity matters	Corporate income tax payable mainly on distributed profits (dividends etc.), supporting reinvestment incentives	Innovation support mainly via broader ecosystem; key lever is reinvestment-friendly corporate taxation	Strong scaling incentives via retention/reinvestment; model often cited for tax simplicity and growth orientation
Ireland	Startup ecosystem supported by broader tax framework; attraction for high-tech investment	Standard corporate system combined with strong innovation levers	R&D tax credit increased to 30% for periods starting on/after 1 Jan 2024 (official Revenue); (policy developments reported toward 35% in late 2025)	Strong innovation-commercialization incentives; high relevance for scalable digital firms and multinational R&D
Netherlands	General SME/startup environment; high institutional quality	Standard corporate system with a targeted innovation channel	Innovation box reduces tax on qualifying innovation profits to 9% (official business.gov.nl and government.nl)	Strong incentive to locate IP and innovation profits; suits scaling firms with R&D outputs and protected/intended IP
Poland	Entry conditions exist within general PIT/CIT; active pro-innovation toolset	Standard CIT (with SME rate) and multiple innovation reliefs	IP Box: 5% on qualified IP income (official podatki.gov.pl); R&D relief described by gov.pl (deductions up to 200% in described design)	

Source: created by the author

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This divergence reflects different development stages. EU tax regimes prioritize scaling, investment, and innovation commercialization, while Ukraine's tax levers prioritize entry, survival, and resilience. From a dynamic perspective, Diia.City represents an institutional attempt to bridge this gap by introducing EU-like investment incentives while preserving competitive tax conditions.

The integration of formal models, hypotheses, and empirical logic (Table 2.5) confirms that tax levers exert a differentiated and context-dependent influence on digital entrepreneurship. In Ukraine, simplified taxation has been a powerful catalyst for entry and resilience under prolonged external threats, while special regimes aim to facilitate structural upgrading. Comparative analysis with the EU highlights a trade-off between flexibility and scalability, underscoring the need for gradual convergence rather than abrupt harmonization.

The formulation of hypotheses H1 and H2 captures a fundamental structural tension inherent in Ukraine's digital taxation model. On the one hand, simplified taxation regimes significantly reduce entry barriers for digital entrepreneurs by lowering effective tax burdens and administrative costs, thereby encouraging formalization and rapid market entry. On the other hand, prolonged reliance on simplified regimes may constrain firm growth, capital accumulation, and integration into higher value-added segments of the digital economy. Empirical validation of these hypotheses would therefore substantiate the existence of an entry - scaling trade-off and provide analytical support for the "policy ladder" approach developed in the simulation analysis, according to which low-friction entry mechanisms must be complemented by credible and predictable pathways toward corporatization and investment-oriented growth.

Hypotheses H3 and H4 extend the analysis by explicitly linking tax levers to the resilience of digital entrepreneurship under prolonged external threats. These hypotheses differentiate between two analytically distinct dimensions of resilience. Hypothesis H4 focuses on survival and continuity effects, positing that tax relief measures and deferred tax obligations enhance the capacity of digital entrepreneurs to maintain operations during periods of heightened uncertainty and liquidity constraints. Hypothesis H3, by contrast, addresses structural upgrading, suggesting that targeted tax regimes designed for the digital sector contribute to higher value added, export performance, and innovation activity.

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Table 2.5. Mapping Hypotheses to Indicators, Models, and Expected Signs

Hypothesis	Core theoretical claim	Dependent variable(s)	Key explanatory indicator(s)	Control variables	Model type / specification	Expected sign(s)
H1	Lower effective tax burden and simplified administration increase entry and formalization of digital entrepreneurs	Density of digital entrepreneurs (per 1,000 economically active population); number of registered digital FOPs	Effective tax burden on digital entrepreneurs; dummy for simplified regime usage	Population density; digital infrastructure; education level; regional income	Panel FE regression at oblast level	- (tax burden); + (simplified regime)
H2	Simplified regimes stimulate entry but constrain scaling and capital accumulation	Average firm size in digital sector; share of incorporated digital firms; investment per firm	Share of digital entrepreneurs under simplified regime	Market size; access to finance; human capital	Panel FE; cross-sectional robustness	- (scaling indicators)
H3	Targeted digital tax regimes increase value added, exports, and innovation	Digital sector value added; digital exports; R&D expenditure in digital firms	Participation in special digital regimes (e.g., Diia.City dummy)	Exchange rate; global demand; sector structure	Difference-in-differences (pre/post regime)	+
H4	Tax relief and deferrals improve survival and resilience under external shocks	Survival rate of digital firms; continuity of registrations; employment stability	Crisis-period tax relief intensity; deferral measures	Shock intensity (damage, IDPs); infrastructure disruptions	Panel FE with crisis interaction	+
H5	Institutional quality amplifies the effectiveness of tax levers	Same as H1 - H4 (interaction effects)	Interaction term: tax lever × institutional quality (e.g., governance index, fiscal capacity)	Regional fixed effects; year effects	Panel FE with interaction	+ (interaction)
H6	Ukraine's simplified taxation increases entry but yields weaker scaling compared to EU digital tax regimes	Entry rates vs. scaling indicators (cross-country)	Country-level tax regime indicators (simplified vs. corporate/R&D-based)	GDP per capita; digital readiness; institutional quality	Cross-country panel or pooled OLS	+ (entry); - / 0 (scaling)

Source: created by the author

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Hypothesis H5 introduces an institutional mediation perspective, ensuring that the empirical model does not reduce observed outcomes to the mechanical effects of tax rates or fiscal incentives alone. By positing governance capacity and regulatory predictability as moderating factors, this hypothesis highlights the role of institutional quality in shaping the effectiveness of tax levers. In this framework, favourable tax conditions are necessary but insufficient for digital entrepreneurship development; their impact depends on the broader institutional environment, including administrative competence, legal stability, and trust between the state and entrepreneurs.

Finally, hypothesis H6 anchors the comparative dimension of the analysis by situating Ukraine's digital tax regime within a broader European context. Rather than relying on descriptive benchmarking, this hypothesis enables causal inference regarding the relative effects of different tax models on entry, scaling, and innovation outcomes. By contrasting Ukraine's entry-oriented, simplified taxation approach with the more corporatized and innovation-focused tax regimes prevalent in the European Union, the analysis can identify structural trade-offs and convergence challenges. This comparative logic enhances the analytical contribution of the monograph by linking national policy choices to broader patterns of digital entrepreneurship development across institutional environments.

A further analytical dimension within this framework concerns the dynamic consistency and time horizon of tax policy effects on digital entrepreneurship. While hypotheses H1 - H4 primarily capture short - to medium-term behavioural responses - such as entry, survival, and immediate innovation outcomes - long-term development trajectories depend on whether tax levers generate stable expectations regarding future regulatory and fiscal conditions. In environments characterized by prolonged external threats, uncertainty is not episodic but structural. Consequently, digital entrepreneurs form expectations not only about current tax burdens but also about the credibility of tax regimes over time.

From this perspective, the effectiveness of a "policy ladder" approach hinges on its perceived irreversibility and institutional anchoring. If simplified regimes are viewed as temporary or politically contingent, entrepreneurs may rationally prioritize short-term income extraction over reinvestment and scaling. Conversely, if transition pathways toward corporate and innovation-oriented tax regimes are credible, rule-based, and insulated from abrupt policy

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shifts, tax levers can influence intertemporal decision-making, encouraging longer planning horizons, capital deepening, and organizational upgrading. This dynamic channel is particularly relevant for Ukraine, where post-crisis reconstruction and European integration introduce both opportunities and uncertainties regarding future tax harmonization.

Moreover, this dynamic perspective highlights a potential coordination problem between entrepreneurs and the state. Entrepreneurs may delay scaling until institutional guarantees are strengthened, while the state may hesitate to expand incentives without evidence of scaling behavior. Addressing this coordination problem requires not only fiscal instruments but also signaling mechanisms - such as multi-year tax commitments, grandfathering clauses, and transparent alignment with EU regulatory trajectories - that reduce strategic uncertainty.

Integrating this temporal and expectation-based dimension reinforces the central argument of the chapter: tax levers influence digital entrepreneurship not merely through static cost - benefit calculations, but through their interaction with institutional credibility, crisis-induced uncertainty, and long-term development narratives. Recognizing this interaction is essential for designing tax policies that support not only the resilience but also the structural maturation of digital entrepreneurship in economies operating under prolonged external threats.

An additional layer of analysis emerges when tax policy for digital entrepreneurship is explicitly situated within the context of European integration and prospective tax harmonization. For Ukraine, the design of tax levers cannot be considered solely as a domestic policy choice; it is increasingly shaped by alignment pressures stemming from EU accession dynamics, including convergence with OECD/G20 BEPS initiatives, state-aid rules, and digital taxation frameworks. This creates a complex policy environment in which the state must simultaneously preserve the flexibility and competitiveness of its digital entrepreneurship ecosystem and ensure long-term compatibility with European regulatory standards.

Within this context, tax levers acquire a signaling function vis-à-vis both domestic and international stakeholders. Multi-year commitments to specific tax regimes, the legal entrenchment of special digital frameworks, and transparent roadmaps for gradual convergence with EU norms reduce strategic uncertainty for entrepreneurs and investors. For digital entrepreneurs, particularly those considering scaling or relocation decisions,

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such signals are often as influential as current tax rates. A credible alignment strategy can therefore mitigate fears of abrupt regime discontinuation and encourage long-term investment, even if short-term fiscal advantages are gradually moderated.

Furthermore, European integration reshapes the comparative benchmark against which Ukrainian digital entrepreneurs evaluate domestic tax conditions. As cross-border mobility of digital labor and capital increases, relative rather than absolute tax advantages become decisive. In this setting, the effectiveness of Ukraine's tax levers depends on their capacity to offer a coherent value proposition: lower entry barriers and administrative simplicity in early stages, combined with predictable and innovation-oriented tax treatment at later stages. This sequencing aligns with EU practices that emphasize corporate stability, R&D incentives, and intellectual property commercialization, while allowing Ukraine to preserve its resilience-oriented strengths during the transition period.

To synthesize the analytical arguments developed throughout this chapter, the causal logic linking tax levers and digital entrepreneurship development under prolonged external threats can be represented through a conceptual pathway suitable for graphical illustration in the monograph. In this pathway, tax levers (including simplified regimes, special digital frameworks, and crisis-related relief measures) constitute the initial policy inputs. These levers shape entrepreneurs' expectations by influencing perceived fiscal predictability, compliance costs, and long-term regulatory credibility. Expectation formation, in turn, affects entrepreneurial behavior along two key dimensions: entry and formalization at early stages, and scaling, investment, and innovation at later stages.

These behavioral responses interact with institutional capacity and crisis intensity to produce differentiated outcomes in terms of territorial resilience, structural upgrading, and inequality. Where tax levers are predictable and institutionally anchored, digital entrepreneurship contributes to economic continuity and gradual maturation of the digital ecosystem. Where tax policy is unstable or weakly coordinated with broader governance reforms, digital activity may remain fragmented, short-term oriented, and vulnerable to external shocks. This conceptual pathway underscores that tax levers do not operate in isolation but function as part of a broader adaptive governance system linking fiscal policy, institutional credibility, and long-term development trajectories.

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Together, the integration of EU accession dynamics and the conceptual pathway perspective reinforces the section's central conclusion: effective tax policy for digital entrepreneurship under prolonged external threats must be forward-looking, institutionally credible, and strategically sequenced. Only under these conditions can tax levers support not only immediate resilience and entry, but also the sustained scaling and integration of digital entrepreneurship into both national and European economic systems.

Conclusions. The analysis demonstrates that tax levers exert a multidimensional influence on digital entrepreneurship development in Ukraine. Under prolonged external threats, taxation policy shapes not only economic incentives but also institutional trust, spatial distribution, and resilience of the digital economy. Simplified taxation has functioned as a powerful resilience mechanism, while emerging regimes such as Diia.City represent strategic attempts to transition toward a more mature and investment-oriented digital ecosystem.

Ultimately, tax levers cannot substitute for broader institutional reform, but they remain a critical component of an effective development strategy. Their success depends on coherence, predictability, and alignment with the structural realities of digital entrepreneurship and the broader socio-economic challenges facing Ukraine.

This section has examined the role of tax levers in shaping the development of digital entrepreneurship in Ukraine under conditions of prolonged external threats. The analysis demonstrates that taxation policy in the digital economy performs a function that extends well beyond revenue generation. In crisis-affected and institutionally transforming contexts, tax levers operate as strategic instruments of adaptive governance, influencing entrepreneurial entry, survival, scaling behavior, and long-term structural transformation.

The theoretical analysis confirms that digital entrepreneurship constitutes a structurally distinct object of taxation, characterized by high mobility, reliance on intangible assets, and sensitivity to regulatory and fiscal uncertainty. Under such conditions, simplified and predictable tax regimes substantially reduce entry barriers and compliance costs, encouraging formalization and supporting economic continuity. In Ukraine, the widespread use of simplified taxation by digital entrepreneurs has functioned as a resilience mechanism, enabling rapid adaptation and income generation during periods of heightened uncertainty.

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At the same time, the chapter has shown that reliance on simplified tax regimes generates an inherent entry - scaling trade-off. While simplified taxation is highly effective in stimulating entrepreneurial entry and short-term survival, it may constrain firm growth, capital accumulation, and integration into higher value-added segments of the digital economy. Formal modeling and scenario simulations illustrate that tax systems optimized exclusively for entry risk institutional lock-in, where digital entrepreneurship remains fragmented and undercapitalized. These findings underscore the analytical relevance of a "policy ladder" approach, in which low-friction entry mechanisms are complemented by credible and predictable pathways toward corporatization, investment, and innovation.

The introduction of targeted digital tax regimes, such as Diia.City, represents an institutional attempt to address this structural limitation. The chapter's formal hypotheses and empirical framework suggest that such regimes can support value creation, export performance, and innovation, provided they are embedded within a stable and trustworthy institutional environment. The effectiveness of tax levers is therefore shown to be conditional upon governance capacity, regulatory predictability, and institutional credibility. Favorable tax rates alone are insufficient to induce scaling behavior if entrepreneurs perceive heightened risks of policy reversal or administrative arbitrariness.

The crisis dimension further refines this conclusion. Under prolonged external threats, tax policy influences not only growth trajectories but survival probabilities. Temporary tax relief, deferred obligations, and administrative flexibility function as automatic stabilizers that preserve liquidity and reduce exit from the formal digital economy. However, crisis-oriented tax measures must be integrated into a longer-term development strategy to avoid reinforcing short-termism and disincentivizing investment.

The EU comparative perspective situates Ukraine's tax model within a broader spectrum of digital entrepreneurship policies. Whereas many EU member states prioritize scaling and innovation commercialization through corporate-based taxation, R&D credits, and IP regimes, Ukraine's approach emphasizes flexibility, entry, and adaptability. This divergence reflects different stages of digital ecosystem maturity and crisis exposure. The analysis indicates that abrupt convergence toward EU-style taxation could undermine Ukraine's adaptive advantages, while gradual and strategically sequenced alignment - preserving entry flexibility while strengthening scaling

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incentives - offers a more sustainable pathway.

Finally, the chapter emphasizes the dynamic and expectation-based nature of tax policy effects. Tax levers influence digital entrepreneurship not only through current cost structures but through their signaling role in shaping long-term expectations. Credible multi-year commitments, transparent transition pathways, and alignment with European regulatory trajectories are therefore essential for extending entrepreneurial time horizons and encouraging structural upgrading.

In sum, the chapter concludes that tax levers are a critical determinant of digital entrepreneurship development in Ukraine, but their effectiveness depends on coherence, institutional anchoring, and strategic sequencing. When designed as part of an adaptive and forward-looking governance framework, tax policy can simultaneously support resilience, inclusiveness, and long-term competitiveness of the digital economy under prolonged external threats.

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Section 2.2. Conceptual Basis for Assessing the Level of Digitalization of the Construction Sector

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***Abstract**. The full-scale war against Ukraine has intensified the need for rapid reconstruction and has repositioned the construction sector as a strategic driver of economic recovery, where digitalization becomes a prerequisite for resilience, transparency, and efficiency across the real and financial segments of the economy. This study aims to deepen the theoretical and methodological foundations for assessing the level of digitalization in the construction sector and to justify an improved mechanism that supports post-war recovery and long-term competitiveness. The research synthesizes contemporary literature on construction digitalization and integrates multi-level analytical tools. It proposes a four-component interaction model "State, regions, higher education institutions, business environment," links sector dynamics to the enterprise life cycle via the Adizes framework and adapts an assessment of financial sustainability to digitalization processes. SWOT is combined with PEST and PESTLE, while portfolio matrices (BCG, GE/McKinsey, Shell/DPM, Hofer/Schendel, ADL/LC) support strategic alternative selection. The study formalizes a general integral indicator for digitalization level based on grouped indicators that reflect macro, regional, higher education, and firm-level determinants, enabling classification into stability zones from absolutely stable to catastrophic. It also explains how BIM and digital twins can reduce costs and increase adaptability during life cycle transitions, and it outlines digitalization pathways that support the rental housing market and project lifecycle efficiency. A coherent assessment architecture is developed to address the absence of universal evaluation approaches and to align digital transformation with stakeholder coordination and reconstruction priorities, strengthening decision-making under environmental uncertainty. Future work should validate the proposed indicators empirically using Ukrainian regional and firm datasets, test sensitivity of weights across life cycle phases, develop benchmarking with international cases, and operationalize the mechanism through digital data platforms for continuous monitoring.*

Keywords: *construction sector; digitalization; BIM; digital twins; blockchain; integral indicator; life cycle model; Adizes; SWOT; PESTLE; investment policy; post-war reconstruction.*

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1. The war and reconstruction context as a driver of digitalization in the construction sector. In the context of russia's full-scale war against Ukraine, there was a radical change in all processes in society, the conditions for the functioning of business, and, accordingly, the restructuring of business processes, which became an incentive for the growth of business social responsibility.

Against the background of the global problems of our time, internal socio-economic, political, and environmental problems have also become more acute, and the social responsibility of business has ceased to be a call for proactive business actions, but also an urgent necessity to ensure the survival and future prosperity of the state as an independent, self-sufficient, economically prosperous state, and business itself has become the driving force of all changes in society.

An important role in ensuring the reconstruction of the state in the post-war period and the period of post-war economic recovery of Ukraine belongs to the construction sector and the level of its digitalization as a catalyst for transformation processes in all sectors of the economy due to the high level of integration of the construction sector into the real and financial sectors.

The situation in the real estate market is a kind of indicator of the level of dependence of the construction sector on trends in financial markets, social, economic and financial policy of the state, in particular regarding methods of state regulation of the industry and direct state support for the sector (Tsilenko, 2013).

A significant contribution to the study of issues related to the digitalization of the construction sector has been made in the works of a large number of authors, in particular on the use of various technologies for this purpose to increase efficiency, quality and sustainability. Some studies have focused on the importance of integrating digital tools, such as: building information modeling (BIM), digital twins and blockchain, which are bringing fundamental transformational changes to construction practices.

The key contributions of various authors in this field are as follows:

- the importance of introducing building information modeling (BIM), automation, and blockchain as key elements, as well as considering new paradigms that are gaining relevance in the languages of russia's full-scale war against Ukraine - smart contracts and modular construction, and this is generally evidence of the construction sector's transition to more innovative practices (Ametepey, Aigbavboa, Addy, & Thwala, 2024);

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- in challenges and success factors (although digital transformation is important, the construction sector faces significant challenges, including high costs and low productivity) using the technology-organization-environment framework (Chen, 2023);

- the impact of digital technologies on project management, including "digital twins" and smart building technologies, which will positively affect project management by increasing efficiency and safety (Zerafat, Daniel, & Gyoh, 2023), the so-called "digital twin adoption" provides significant advantages for project planning and execution and highlights their transformative potential (Park, Lee, Son, Yu, Lee, & Kim, 2024).

However, despite the prospects for the development of digitalization processes, the construction sector, according to some conclusions (Chen, 2023), remains one of the least digitized in the world, which indicates the relevance of the research topic and the feasibility of conducting further research on developing a mechanism for its digitalization to overcome existing barriers and maximize the benefits of digitalization.

2. External and internal factors, barriers, and the ambivalence of digitalization. The digitalization of the construction sector largely depends on the level of its development and is influenced by external and internal factors, the main ones being:

- low level of digital activity of domestic construction companies and insufficient level of readiness for the implementation of digital technologies at all levels of management;

- fragmented use of digital solutions and lack of a comprehensive approach to their implementation. In many companies, digitalization is implemented "pointwise", which does not ensure proper efficiency;

- the dispersion of investments in digital transformation, which is largely due to the lack of centralized state support and insufficient funding for digital initiatives. This is generally a factor inhibiting the development of innovations in construction;

- imperfection of the organizational and economic mechanism for managing digital processes. The lack of a coordinated strategy for the digitalization of the construction industry, as well as inefficient models for financing digital projects, limit opportunities for the development of the industry.

However, the large-scale introduction of digital technologies into construction processes is restrained by the accumulation of a number of

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negative trends characteristic of the development of the real and financial sectors of the economy, taking into account the ambivalence of digitalization, the dualistic nature of which is manifested in the fact that it provides the practical implementation of this process in terms of the implementation of effective digitalization mechanisms based on the study of factors influencing the implementation of the economic interests of business entities, taking into account the interests of stakeholders, and on the other hand, as a concept, it is based on economic laws and regularities and involves the use of digitalization principles, thus contributing to the intensive development of the construction sector as a whole.

Taking this into account, digitalization is an ambivalent category: on the one hand, increasing its efficiency contributes to increasing the level of economic development of companies in the construction sector, and on the other hand, the implementation of company development management strategies based on developed effective mechanisms is decisive in the implementation of digitalization as a concept and the functioning of companies in the industry as a whole.

In general, successful digital transformation of the construction sector is possible if a comprehensive approach is implemented, including the activation of innovative activities, the creation of an effective mechanism for financing digital projects, and the formation of a strategy for the development of digitalization at the state level and their corresponding transfer to the regional and local levels.

3. The logic of the proposed approach to assessing the level of digitalization. In connection with the above, the need to adapt to the conditions of a changing external environment is becoming more urgent, which can be achieved through the creation, use and implementation of digitalization processes, in particular, through their interaction with the business environment, which is actualized by ensuring the proper density of communication in the interaction of the type "State – regions – higher education institutions – business environment" between the elements of the four-component model, which characterizes the dependence between them and will contribute to achieving a synergistic effect in the development of the economy as a whole using functional synergy between different groups of indicators.

In general, in the process of evolution of the theory and practice of the development of digitalization processes, a number of conceptual and

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methodological approaches have been developed using individual methods and, in general, a wide arsenal of tools has been created for choosing mechanisms and strategies for such development. This is partly due to the fact that in the current conditions of the development of the Ukrainian economy, the rational use of the potential of business entities is an important prerequisite for increasing the efficiency of their management and affects the possibility of their achieving strategic goals and objectives, which, in turn, involves the use of their ability to digitize as an important factor in such development.

However, given the nature of digitalization, there are no universal methods and methodological approaches to its assessment in modern science and practice. This contributes to the emergence of inconsistency in the views of scientists regarding the determination of its level and determines the feasibility of conducting a study of methods for assessing the ability of entities in the construction sector to digitize in order to identify a rational option for conducting such an assessment, taking into account the influence of external and internal environmental factors and thus ensuring the possibility of harmonizing the results obtained with the strategic development goals of companies in this sector.

In this context, construction companies are a platform for creating, implementing innovations and generating knowledge, skills and abilities and using them in research activities in the case of close interaction of higher education institutions with the business environment and the state. This implementation requires the development and implementation of measures to adapt them to the conditions of the changing external environment and provision.

The model of the life cycle of an organization according to Ichak Adizes is informative and allows linking the elements of a four-component model of the type: "State – regions – higher education institutions – business environment", which is characterized by specific features and challenges and serves as an auxiliary for identifying the current stage of the organization's development and developing and using appropriate measures to transition to the next phase or avoid decline (Zosym, 2021); (Trans.eu, 2021).

For business entities in the construction sector, the life cycle of this model can be represented as a closed dynamic system, organizational development is a continuous, cyclical process, within which the transition between phases is carried out through a system of interconnected crises. At different stages of formation, growth and maturity, crises of trust, autonomy,

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professional management and corporate relations dominate, which are caused by a combination of external market uncertainty and internal organizational and managerial contradictions. Overcoming these crises is a necessary prerequisite for the transition to a higher level of company development, while ignoring them or ineffective response leads to stagnation and decline. According to this model, the crisis has a dual nature: on the one hand, it fixes the limits of the effectiveness of the current management system, on the other hand, it acts as a catalyst for innovation and organizational renewal. Thus, the management of the life cycle of a corporation is interpreted as a purposeful process of identification, forecasting and constructive solution of problems associated with the occurrence of events related to crises of a market, managerial and interpersonal nature, which ensures the maintenance of a dynamic balance between growth, structural complexity and the ability to adapt in a changing external environment. And it is they who act as a mechanism for the transition between the phases of the life cycle and determine possible trajectories of further development. At the early stages, crises of trust and autonomy, reinforced by a high level of market uncertainty, dominate. They reflect the contradiction between the entrepreneurial flexibility of a young company and the need to formalize management decisions and the distribution of powers. Overcoming these crises is a prerequisite for corporations to enter the stage of intensive growth and professionalization of management.

In the growth phase, crises of professional management and corporate relations intensify, which is due to the complexity of the organizational structure, the scaling of the business and the intensification of market competition. At this stage, there is a need to transition from an intuitive, founding style of leadership to a systemic, professional management that can provide a balance between strategic flexibility and operational stability.

Mature corporations are characterized by the dominance of crises of autonomy and management/corporate relations, which reflect conflicts between centralized control and decentralization, between different levels and links of management, between owners, top management and personnel. At this stage, the key factors for maintaining viability become the quality of communications, the consistency of stakeholder interests and the ability for organizational learning.

The lower part of the cycle demonstrates the alternative of further development: in case of ignoring the accumulated crises, the organization

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enters a phase of stagnation and decline, which is accompanied by recurring crises of trust, relations and management. In contrast, a timely innovative response to crisis phenomena can initiate "renewal" and launch a new round of the life cycle. Thus, the model emphasizes that the crisis is not only a threat, but also a catalyst for strategic changes, and corporate life cycle management involves systematic work on identifying, preventing and constructively resolving crisis situations at each stage of the development of organizations.

In general, the Adizes PAEI model describes the stages of an organization's development from its foundation to its decline and determines the optimal actions for each of them. Ichak Adizes described the roles of management within the scope of the participants' responsibilities (Zosym, 2021): P (Producer) – producer – short-term performance; A (Administrator) – administrator – short-term performance; E (Entrepreneur) – entrepreneur – long-term performance; I (Integrator) – integrator – long-term performance.

The theory was developed for business and later spread to other areas of society. In business, E and I cannot be delegated, only P and A are programmable, in education for the improvement of P and A (professional disciplines, courses for systematization and control of processes). Education is needed to improve E and I.

To use the enterprise life cycle model in conjunction with the construction industry life cycle, it is important to combine the parameters for assessing the level of its digitalization.

4. The relationship between the construction sector life cycle model and the life cycle of business entities. The development of construction enterprises is an integrated, cyclical process, within which the life cycle of the enterprises themselves is structurally and functionally linked to the life cycle of the objects they create. The stages of formation, growth and decline of business entities correlate with the sequence of stages of design, construction, operation and decommissioning of construction objects, which determines the mutual influence of economic and organizational decisions and technical and technological parameters of projects.

The parameters and results of the implementation of construction projects are interdependent: at each stage they directly affect the financial and economic results and strategic positioning of enterprises, while management decisions and innovative potential of enterprises determine the efficiency of the objects passing through the full construction cycle. This approach allows us to consider the management of the development of construction enterprises

https://doi.org/10.36690/CIDI-EME
ISBN 978-9916-9320-3-2 (pdf)

not only as an intra-corporate process, but as a multi-level system of coordination of resources, projects and stages of the object life cycle. Accordingly, ensuring the sustainability and competitiveness of enterprises involves the systematic coordination of strategic, operational and investment decisions of economic, technological and environmental goals with the dynamics of the life cycles of construction objects, which creates the prerequisites for increasing the efficiency, innovation and environmental performance of activities in the long term.

The construction industry life cycle, combined with the enterprise life cycle model of Ichak Adizes, has changed significantly in recent years. This evolution is characterized by the integration of digital technologies, regulatory changes, and adaptive strategies in response to economic challenges.

To deepen the research, a modified method for assessing financial sustainability and its adaptation to the processes of digitalization of the construction sector are proposed.

The essence of the method is to identify potential risk areas and determine significant costs in the event of a transition from a zone of absolutely stable digitalization level to a zone of catastrophic ones, provided that the areas of activity change, with the determination of the overall level of digitalization depending on the stages of the life cycle and group indicators and the corresponding determination of weight indicators by groups of indicators with their corresponding incorporation into the formula series according to the four-component model:

- an integral indicator for a group of indicators that characterize the level of digitalization at the country level within the digitalization of the economy and indicate the possibility of carrying out activities (taking into account the specifics of enterprises in the industry) from the point of view of the influence of external environmental factors (DV 1);
- an integral indicator for a group of indicators that characterize the level of digitalization at the regional level, taking into account the influence of meso-level factors in the system of influencing factors on the level of digitalization of the construction sector and indicate the dependence of the construction sector on the influence of external and internal environmental factors (RV 2);
- an integral indicator for a group of indicators that characterize the impact of the higher education sector in general and higher education institutions on the level of digitalization of the construction sector, taking into

https://doi.org/10.36690/CIDI-EME
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account the relevant influencing factors (ZV 3);

- an integral indicator for a group of indicators that characterize the influence of internal factors affecting enterprises in the construction industry on the level of its digitalization (BVS 4).

The result is the formation of a four-component indicator, the group indicators of which are incorporated into the formula series and illustrated using an equation:

$$S = \{S(\pm X1), S(\pm X2), S(\pm X3), S(\pm X4)\}, \qquad (2.9)$$

where S is a set consisting of elements S(±VD1), S(±VR2), S(±VZVO3), S(±VBS4); S(±Xi) is the function S(x)S(x)S(x), which is defined for +Xi and-Xi.

The type dependency must be maintained:

– Absolutely stable level (VD1>0, VR2<0, VZVO3>0, VBS4>0): the construction sector is dependent on the influence of all factors.
– Mostly stable level (VD1>0, VR2=0, VZVO3>0, VBS4>0): the construction sector is dependent on the influence of factors at the state level, the level of VZVO, and the influence of the business environment.
– Unstable level (VD1<0, VR2<0, VZVO3>0, VBS4>0): the construction sector is independent of the influence of factors at the macro- and regional levels but significantly depends on the factors of influence of the higher education sector and the business environment and has the potential to restore stability.
– Critical (VD1<0, VR2>0, VZVO3<0, VBS4>0): the construction sector is dependent on the influence of regional factors and the influence of the business environment, which contributes to the increase in threats to the existence of the industry, but has the potential for the development of the industry.
– Pre-catastrophic (VD1<0, VR2=0, VZVO3=0, VBS4=0): increasing threat of industry decline.
– Catastrophic (VD1<0, VR2>0, VZVO3<0, VBS4<0): catastrophic state of industry development and complete loss of recovery opportunities.

Analyzing each possible state makes it possible to assess the current level of digitalization and predict the existence of risks or opportunities for development.

The method is supplemented by the use of the Laplace criterion, according to which all states of nature Pj are equally probable and each of

https://doi.org/10.36690/CIDI-EME
ISBN 978-9916-9320-3-2 (pdf)

them corresponds to a probability (Pi), which is determined by formula 2.10 and the arithmetic mean value of the options for digitalization levels (formula 2.11).

$$p_i = \frac{1}{n} \quad (2.10)$$

$$W(A_i) = \frac{1}{n}\sum_{j=1}^{n} a_{ij} \quad (2.11)$$

The value ($W(A_i)$)is adapted according to the scale of correspondence to the levels of digitalization using the golden ratio method (Table 2.6).

Table 2.6. Scale for determining the level of digitalization

Dependence between group indicators	Levels of digitalization	Overall level of digitalization
VD 1>0, BP2 < 0, VZVO3>0, VBS4>0	Absolutely stable level	0.855-1
VD1 > 0, VR2=0, VZVO3 > 0, VBS 4 > 0	Mostly stable level	0.619-0.854
VD1<0, BP2 < 0, VZVO3 > 0, VBS 4 > 0	Unstable level	0.383-0.618
VD1<0, BP2 > 0, VZVO3 < 0, VBS 4 > 0	Critical level	0.147-0.382
VD1<0, BP2 = 0, VZVO3 = 0, VBS 4 =0	Pre-catastrophic level	0.001-0.146
VD1<0, BP2 > 0, VZVO3 < 0, VBS 4 < 0	Catastrophic level	0

Source: created by the authors

When constructing a general integral indicator for assessing the level of digitalization, it is advisable to take into account the objective structure of the elements that form the system, each of which is expressed in specific value indicators of an integrative nature (the so-called KPIs), which allows combining financial and non-financial criteria with the possibility of interaction of the construction sector with stakeholders at all levels of management and a determinant of the development of the state and its economic security in the context of implementation and taking into account the influence of external and internal environmental factors on the state of the industry and the real estate market through the implementation of a set of measures aimed at ensuring the appropriate level of development and in the vector of implementation of the state's socio-economic policy.

Taking into account the presence of powerful strengths identified through SWOT analysis, it is advisable to form the main architecture of the construction sector digitalization mechanism in accordance with the general strategy for the development of the industry and the appropriate coordination of resource strategies, provided that the industry development strategies are

https://doi.org/10.36690/CIDI-EME
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balanced, the interaction of their individual types in the strategic set is justified, which contributes to their mutual reinforcement - achieving a synergistic effect of economic development through the accumulation of resources (the interdependence between groups of strategic resources is shown in Figure 2.2) and expanding the scale of the industry, which contributes to the optimization of inter-industry relations and ensuring economic growth of the state as a whole.

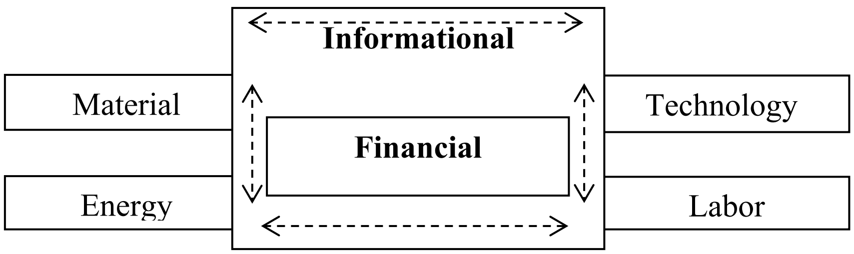

Figure 2.2. Schematic diagram of the structure and interconnection of enterprise resources

In the future, taking into account the main factors of the external and internal environment, it is important to appropriately intensify efforts at all levels of management regarding their development, and this will allow to achieve an increase in the efficiency of the industry and to some extent to level the influence of weaknesses (factors), which, in turn, contribute to the increase in threats to the effective development of the industry in combination with PEST analysis (Bahorka, Kadyrus, & Yurchenko, 2022) and PESTLE analysis.

In the process of conducting a SWOT analysis (Bahorka, Kadyrus, & Yurchenko, 2022), research is carried out on the following components: S (strength), W (weakness), O (opportunities), T (threats).

The characteristics of the components of PEST analysis (Ministry of Digital Transformation of Ukraine) are as follows:

P: stability of political power and the existing government; bureaucratization and level of corruption; tax policy, media independence; industry protectionism, presence of state-owned companies in the industry; degree of intellectual property protection, copyright law; environmental legislation; future and current legislation regulating the rules of work in the industry; possibility of military action in the country;

E: economic growth rates; inflation rate and interest rates; exchange rates

https://doi.org/10.36690/CIDI-EME
ISBN 978-9916-9320-3-2 (pdf)

of major currencies; unemployment rate, size and conditions of remuneration; level of development of entrepreneurship and business environment; monetary and fiscal policy of the country; degree of globalization and openness of the economy; level of development of the banking sector;

S: level of health care and education; attitude towards imported goods and services; attitude towards work, leisure, retirement; requirements for product quality and service level; lifestyle and consumption habits; development of religion and other beliefs; attitude towards natural and environmentally friendly products; population growth rates; immigration attitudes; family size and structure;

T: level of innovation and technological development of the industry; research and development spending; legislation in the field of technological equipment of the industry; development and spread of the Internet, development of mobile devices; access to the latest technologies; degree of use, implementation and transfer of technologies.

Characteristics of the components of PESTLE analysis (Zosym, 2022):

P: Political: tax policy; environmental regulations; trade restrictions and reforms; tariffs; political stability.

E: Economic: Economic growth/recession; interest rates, exchange rates, inflation and wage levels; minimum wage; working hours; unemployment (local and national); credit availability; cost of living.

S: Sociological: cultural norms and expectations; health consciousness; population growth rates; age distribution; career attitudes; health and safety.

T: Technological: new technologies (in robotics and artificial intelligence, etc.), and the speed of change is becoming relentless and affecting the construction industry and the real estate market.

L: Legal: changes in legislation affecting employment, access to materials, quotas, resources, imports/exports, taxation.

E: Environmental: global warming and the growing need to transition to sustainable resources; ethical sourcing (both local and national), including supply chain intelligence, etc.

Taking into account the proposed four-component model for assessing the level of digitalization, it is advisable to build a level conceptual model of the mechanism for developing and implementing the mechanism, developed at the appropriate stages of formation with appropriate tools (Figure 2.3).

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ISBN 978-9916-9320-3-2 (pdf)

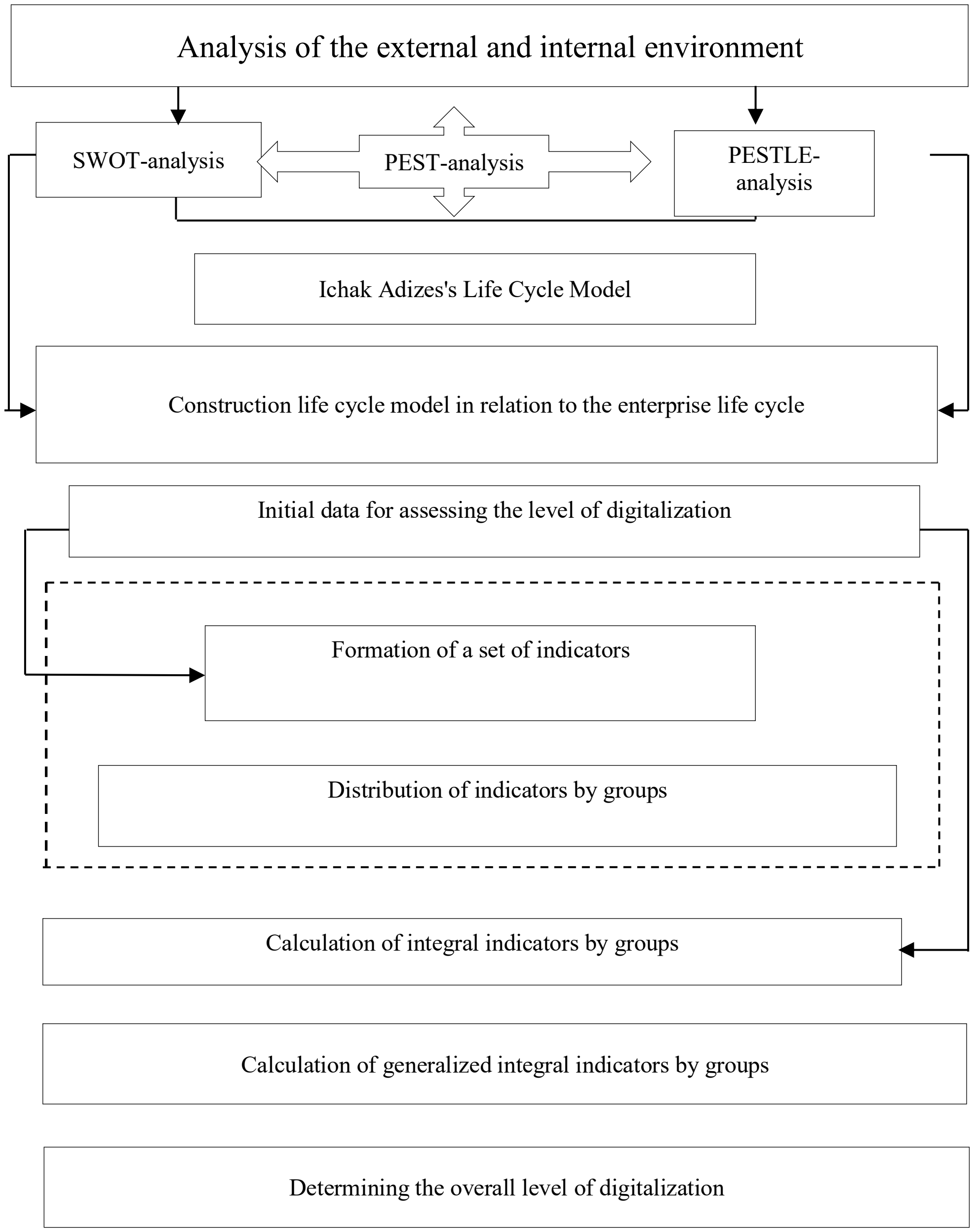

Figure 2.3. Stages of forming an improved mechanism for determining the level of digitalization of the construction sector

Source: formed based on own research and using (Breus, 2018).

The implementation of the above is necessary for the formation of long-term competitive advantages that contribute to adaptation to environmental conditions and the selection of strategic alternatives, in particular, this can be

https://doi.org/10.36690/CIDI-EME
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achieved in the case of a combination of matrix and integral methods of assessing the competitive positions of entities in the construction sector using portfolio analysis methods, such as: BCG, GE/McKinsey, Shell/DPM, Hofer/Schendel and ADL/LC matrices. This will ensure the clarity of the results, however, for an in-depth analysis of the causes of their occurrence, their combined use is important (Breus, & Boiko, 2019). These portfolio analysis methods help companies optimize their business portfolio, determine investment priorities, and develop effective strategies depending on the strength of the influence of external and internal environmental factors.

The BCG Matrix (BCG Matrix, Boston Consulting Group) is used to analyze a company's product portfolio and determine strategic priorities. It is based on two criteria: market growth rate and relative market share and involves the formation of the following quadrants:
"Star" – high growth rate, large market share.
"Cash Cows" – low growth, large market share.
"Difficult children" (question marks) – high growth rate, low market share.
"Dogs" – low growth, small market share.

GE/McKinsey Matrix (GE/McKinsey Matrix, General Electric & McKinsey) is an extended version of the BCG matrix and involves evaluating business units according to the criteria of market attractiveness and company competitiveness. It uses a 9-cell matrix for more flexible analysis and allows you to formulate strategies depending on the positions of strategic business units: invest and develop (high attractiveness, strong position); selective approach (medium attractiveness, medium position); rollback or exit (low attractiveness, weak position).

The Shell/DPM Matrix (Directional Policy Matrix, Shell & Arthur D. Little) is used to evaluate business units based on their competitive position and industry attractiveness. It includes more evaluation criteria than the BCG, allowing for the assessment of long-term investment feasibility. Key strategic decisions include expansion, retention, or exit.

The Hofer/Schendel Matrix (Hofer & Schendel Matrix, Charles Hofer & Dan Schendel) takes into account the industry life cycle (emergence, growth, maturity, decline) and the competitive position of the business unit. It is used to determine strategy depending on the stage of the market life cycle and the company's capabilities and is focused on dynamic strategic planning taking into account changes in the market.

The ADL/LC Matrix (ADL Matrix – Arthur D. Little / Life Cycle Matrix,

https://doi.org/10.36690/CIDI-EME
ISBN 978-9916-9320-3-2 (pdf)

Arthur D. Little) combines the industry life cycle and the company's competitive position. It defines a strategy for each of the 4 stages of the life cycle (inception, growth, maturity, decline). It reflects the long-term strategic prospects of business development.

Thus, it should be noted that the use of a modified mechanism taking into account the influence of external and internal environmental factors allows for an effective assessment of the market positions of construction sector entities and at the same time, supplemented by more detailed methods, in particular integral assessments, for the analysis of cause-and-effect relationships and the possibility of using a combination of the type "Max-Max" – development of the potential for digitalization when taking into account the influence of factors according to the elements of a four-component model of the type: "State – regions – higher education institutions – business environment".

Given that current trends in the construction sector are characterized by the active introduction of digital technologies that transform traditional approaches to the design, construction and operation of residential facilities. In the context of the formation and further development of the rental housing market, digitalization is a key factor in increasing its efficiency, transparency and accessibility.

Digital technologies provide process optimization at all stages of the life cycle of construction projects, which, in turn, contributes to the creation of new opportunities for the development of the rental housing market. The main areas of digitalization in this context include:

1. Implementation of BIM (Building Information Modeling) technologies for real estate design and management, which allows to increase the quality of construction, reduce costs and improve the operational characteristics of residential complexes.

2. Automation and digital management of rental properties based on cloud platforms and mobile applications, which facilitates interaction between tenants, landlords and service companies.

3. Internet of Things (IoT) and smart homes, which help reduce operating costs, increase the level of comfort and safety of residents.

4. Blockchain technologies and smart contracts to ensure transparency of rental relationships, automate financial transactions, and protect the rights of the parties.

The digitalization of the construction sector contributes to the development of the rental housing market through the following main aspects:

https://doi.org/10.36690/CIDI-EME
ISBN 978-9916-9320-3-2 (pdf)

1. The use of digital solutions allows you to reduce the costs of construction, operation and management of residential facilities, which reduces the cost of rent and increases its accessibility for the population.

2. The use of smart contracts and digital identification helps increase the level of trust between market participants, minimizes fraud, and simplifies legal procedures.

3. The development of digital platforms allows for the creation of personalized offers for tenants and the adaptation of living conditions taking into account price offers.

4. The integration of energy-efficient solutions, smart resource management systems, and environmentally friendly materials into the construction process contributes to the formation of a sustainable rental housing market.

The relationship between the digitalization of the construction sector and the life cycle of enterprises is becoming closer as the industry develops. Digital technologies contribute to increasing efficiency, reducing the life cycle of projects and improving competitiveness at various stages of their implementation, and this contributes to the formation of competitive advantages of business entities in this sector.

Digitalization has different impacts at different phases of the life cycle. Initiation phase: characterized by a low level of digitalization, this phase often lacks the technological integration seen in later stages (Begić, Galić, & Dolaček-Alduk, 2022).

Design and planning phase: Characterized by a high level of digitalization but a lower level of automation, which allows the use of advanced modeling and planning tools that simplify project development (Begić, Galić, & Dolaček-Alduk, 2022).

Execution phase: The level of digitalization remains low, but automation is more widespread, facilitating construction processes and increasing operational efficiency (Begić, Galić, & Dolaček-Alduk, 2022).

In general, it should be noted that digitalization in construction varies significantly across different phases of the project lifecycle, with low levels of digitalization at the beginning, high levels but low automation in design, and low digitalization with higher automation in execution. This indicates a complex relationship (Begić, Galić, & Dolaček-Alduk, 2022). Companies operating in the construction industry should adapt their business models according to the phases of development of the industry. In particular, during

https://doi.org/10.36690/CIDI-EME
ISBN 978-9916-9320-3-2 (pdf)

the growth phase, it is advisable to expand activities and attract investments, while during periods of recession, it is advisable to optimize costs and search for new market opportunities.

The transition from one life cycle stage to another is accompanied by a number of challenges, including changing demand, fluctuations in building material prices, and regulatory changes. Companies that identify these risks in a timely manner can better manage them and ensure the stability of their operations.

The use of the latest technologies and principles of digitalization in the construction sector contributes to the extension of the life cycle of enterprises and the preservation of their competitiveness even in times of crisis.

The level of digitalization has a significant impact on business processes. Conversely, while digitalization offers significant benefits, it also creates challenges such as the need for skilled professionals and the potential for increased project management complexity. As the industry adapts, balancing these factors will be critical to a successful digital transformation.

The digitalization of the construction sector is significantly impacting the life cycle of businesses by improving efficiency, sustainability and decision-making processes. This transformation is characterized by the integration of advanced technologies such as digital twins and building information modeling (BIM), which optimize the different stages of a construction project from design to maintenance.

By optimizing resources, digitalization has a significant impact on the efficiency of the industry as a whole. Digital tools contribute to more efficient resource management, reducing waste and costs throughout the project life cycle (Lauria, & Azzalin, 2024).

Digitalization supports the monitoring and management of energy consumption, contributes to the achievement of sustainable development goals and decarbonization efforts (Lauria, & Azzalin, 2024).

Technologies such as BIM allow for comprehensive life cycle assessment and ensure efficient maintenance of buildings over time (Bondarenko, 2024).

The use of digital twins enables proactive maintenance strategies, reduces downtime and extends the service life of structures, improves building lifecycle management by optimizing resource use, energy efficiency and maintenance schedules, ultimately contributing to cost reduction and increased resilience to environmental factors.

https://doi.org/10.36690/CIDI-EME
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Considering that the national economy is an economically and organizationally unified system of interconnected sectors and spheres of human activity, it acts as a holistic organism achieved under the influence of a set of factors, functioning according to certain laws (Bobrov, 2012).

Taking into account the increase in globalization processes (the main consequences of which in modern conditions are: international division of labor, migration on a global scale of capital, human and production resources, standardization of legislation, economic and technical processes, as well as the rapprochement of cultures of different countries (Radionova, Breus, Denysenko, Khaustova, & Matiukh, 2021); (Denysenko, & Breus, 2021); (Shamborovskyi, Nehoda, Demidova, Tarashchenko, & Breus, 2021), which has found its manifestation in all spheres (economic, political, social, etc.), the issue of national economic management has acquired an independent and decisive importance.

In modern conditions, the main models of national economic management are: American, European, German, Swedish, Japanese and Chinese (Table 2.7), each of which has its own characteristics and peculiarities.

Table 2.7. Main models of national economic management

Models of national economic management	Essence and characteristics	Features of the impact on the economy
American (liberal)	A system of economic relations in which its structure is modified depending on current market needs and prospective directions for directing resources. The government's focus is on intensifying innovation processes and supporting the diffusion of scientific and technical developments into the productive sectors of the economy. A qualitatively formed regulatory framework and a rational distribution of powers play an exceptional role.	An effective public-private partnership is being established, in which market needs are the key guidelines and scientific progress contributes to the regional balancing of structural proportions, while stimulating the processes of dynamic economic growth.
European	It is aimed at eliminating territorial asymmetries of development; moving away from the practice of providing sectoral support and subsidies to priority industries (which aims to support competitive interactions in European markets and avoid the formation of monopoly structures); prioritizing the infrastructure direction of development and the	The desire to create favorable conditions for market interactions, which excludes direct state intervention in shaping the direction of structural restructuring of the economy

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Models of national economic management	Essence and characteristics	Features of the impact on the economy
	development of the information economy. The use of this model is typical for countries that are part of the EU and for which an organic combination of individual elements of the Japanese and American models is characteristic.	
German (neoliberal)	Orients state regulation to eliminate obstacles to competition, stimulate the development of small businesses, increase employment, social orientation of market development, economic security for employees, income equalization, social insurance, ensuring minimum wage, there is an extensive system of social benefits	By combining economic and social guidelines, this model achieves an optimal balance between public and individual interests.
Swedish (Social Democratic)	Provides for increased attention to the social sphere, employment levels, social security, labor relations, and a strict income policy	The main guideline is to ensure the most favorable conditions for each subject to reveal their own socially useful activity, active state intervention in the process of income distribution and redistribution, the creation of a strong social protection system, and the dominance of the ideas of equality and solidarity. Implemented in Scandinavian countries and partially in Portugal, Spain
Japanese	It is characterized by excessive state intervention, the government monitors the efficiency of the industries, it can decide on their selective support or complete closure or transfer outside the country. The government carries out its activities within the framework of public-private partnership, develops long-term strategic development plans, which determine the key areas of structural transformations of the economy, in agreement with representatives of big business, which are entrusted with the implementation of the relevant programs. The use of such a model is typical for South Korea and Singapore.	By implementing a policy of active state intervention in the process of structural transformations, the foundation for the development of a high-tech economy has been created and stable rates of economic growth have been achieved. The processes of reducing the resource intensity of production are being stimulated - support for resource-saving technologies as a promising direction for the implementation of innovations, which is reflected at the micro level in the form of the concept of lean production.
Chinese	The main economic functions of the state: formation of a scientific strategy and national economic plans; coordination of regional and sectoral plans and economic relations; active influence on the economic market	There is mobilization and distribution of resources, use of the tax system, mechanisms of monetary circulation, pricing

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Models of national economic management	Essence and characteristics	Features of the impact on the economy
	environment through the development of regulatory acts, improvement of the system of prices, taxes, credits; drawing up plans for the development of science, technology and their active implementation in production; promotion of the expansion of the action of internal and external markets, inclusion of enterprises in their sphere, provision of them with the necessary information about the market situation, opportunities for economic cooperation	

Source: systematized, summarized, and grouped according to data (Denysenko, & Breus, 2021; Derhaliuk, 2019; Bodrov, & Shepetko, 2014; Shashyna, Hrechko, Kavtysh, et al., 2014; Popadynets, 2014; Tulchynska, 2014; Koretskyi, 2002)

Considering the data in Table 2.7, it should be noted that the implementation of existing models of national economic management is possible taking into account Ukrainian realities and can be implemented only if a favorable investment climate is created by activating the investment process within the framework of implementing an effective investment policy.

Countries around the world implement state investment policies, which differ in each of them and have their own characteristics, but they have certain characteristics that contribute to improving their investment climate and increasing the volume of attracted investments and can be used taking into account national characteristics at the level of Ukraine.

The characteristic features and peculiarities of the implementation of such a policy by individual states that are among the 20 countries with the largest volume of foreign direct investment attracted (Holenishcheva, 2016) are given in Table 2.8. Government support for the construction industry, investment programs, and regulatory measures can accelerate or slow down certain phases of the life cycle, which, in turn, affects enterprise management strategies.

Considering the above, it should be noted that in Ukraine, when implementing state investment policy, it is advisable to take into account the probability of implementing the concept of innovative specialization of the state in order to become an exporter of high-tech products, in particular, taking into account the intensification of the development of research and innovation, increasing the share of knowledge-intensive products in production

(Denysenko, Yurynets, Yurynets, & Kokhan, 2020) and the possibility of regenerating the economy as a result of increasing exports of high-tech products (Breus, 2010).

Table 2.8. Characteristic features and peculiarities of the implementation of state investment policy in developed countries of the world

Countries	Characteristic features	Implementation features
USA	Stimulating foreign investors with state control of investments in the most sensitive sectors of the economy	Investment issues are regulated both at the federal level (general requirements are established for foreign investment issues) and at the state level (specific regulations are established for the participation of foreign investors in projects by local governments). Based on long-term and short-term programs that take into account the specific characteristics of the development and needs of the states in accordance with the legislation, the state itself carries out work to attract foreign investment.
China	Attractive investment climate for foreign investors	The volume of foreign investments is taken into account in accordance with the concluded contracts and the volume of their use, which are not always identical, based on the regulatory documents adopted in 2013 by the authorized bodies of China as a continuation of the state policy of improving the investment climate initiated in 2012.
Austria	Freedom for investors to choose investment areas and sources of their financing, except in certain cases where a special permit is required	There is no single state act regulating relations in the investment sphere: the procedure, conditions for implementation, and various forms of their stimulation are enshrined in a number of federal and state acts and directives on specific issues. Foreign investors are granted national treatment on a reciprocal basis, the state does not create direct restrictions on investment in any sectors of the economy, however, in some cases this process may be constrained by the need to obtain a special permit to carry out certain types of economic activity, environmental protection requirements and other regulations not directly related to investment issues. Foreign investments are allowed in all sectors of the economy, except for the defense industry, enterprises and organizations that are financed by the budget (federal railways, post and telegraph, radio and television), as well as industries and activities that are state monopolies (mining, production of tobacco products and alcoholic beverages).
Netherlands	Favorable investment climate, attracting investments taking into account the interaction of the state, business and science	Ease of registration of legal entities, absence of administrative barriers, favorable legal framework, tax preferences, large number of international agreements on avoidance of double taxation. The government consistently implements a strategy of attracting foreign investment based on partnership between the state, business and science, measures are being implemented to protect investments and provide financial support to small and medium-sized businesses. Investment policy is based on competent presentation of investment projects to potential foreign partners,

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Countries	Characteristic features	Implementation features
		there is a specialized state agency for foreign investment – a division of the Ministry of Economy, implementation
Great Britain	Promoting foreign investment. Responsibility for the effective use of investments. Protection of investor rights	The absence of a single law regulating investment activities; regulation of the activities of stock market professionals is maximally separated from the state. Strict responsibility for the effectiveness of their implementation and spending at all levels. The adoption and implementation of investment decisions are carried out on an extra-budgetary and recurring basis. The focus of the investment activity regulation system on protecting the rights of capital owners. Fierce competition between individual financial market participants
France	Low level of control over foreign enterprises operating in the country. Existence of more preferential regulation in relations with foreign investors	Lack of a single law regulating investment activities. "Market access system". system of "prior notification of authorities about intentions to extend the approval period". Clear distinction between direct and other foreign investments with the use of more preferential regulation in relations with foreign investors

Source: systematized, summarized, and grouped according to data (Denysenko, & Breus, 2021; Holenishcheva, 2016; Bohdanenko, 2017)

The experience of European countries' recovery after World War II provides valuable guidelines for Ukraine. In the post-war period, European states were able to carry out large-scale reconstruction, combining their own resources, external assistance, and structural reforms aimed at forming a sustainable economy (Koval, 2024).

One of the key factors in Germany's economic recovery was the Marshall Plan, a US financial assistance program that provided over $13 billion (equivalent to approximately $150 billion in today's terms).

These funds were directed to rebuilding infrastructure, supporting businesses, and stimulating economic development. The main conclusion for Ukraine is the importance of attracting international financial assistance for infrastructure modernization and overall economic recovery.

At the same time, the stability of regulatory policy is critical for attracting investment. Lenders will not risk investing if there is a threat of their being blocked for many years due to decisions of individual government bodies.

Postwar Japan implemented large-scale reforms focused on the development of innovative technologies and the industrial sector. Significant investments in construction and industry became the basis of the country's economic growth (Koval, 2024).

The Japanese experience demonstrates that technological innovation can be a driver of reconstruction, especially in the construction sector. Similar approaches could be effective for Ukraine, given the challenges faced by countries such as Lebanon and Iraq in the 21st century.

After the catastrophic explosion in Beirut in 2020, Lebanon faced an acute shortage of construction materials and a mass exodus of skilled personnel, which has common features with the situation in Ukraine.

The recovery was made possible by international financial assistance and the implementation of economic reforms. This highlights the need for Ukraine to attract external support, and one of the key factors for success is the stability and transparency of state policies.

After the war, Iraq rebuilt its economy through public-private partnerships, which attracted significant foreign investment. The country's National Investment Commission initiated projects worth over $100 billion, which helped rebuild the housing and commercial stock (Koval, 2024).

Ukraine can use this experience and create favorable conditions for attracting investors and creating mechanisms for public-private partnership, which will contribute to the effective reconstruction of the country.

Conclusion. Taking into account the above, it can be stated that the life cycle of the construction industry directly affects the dynamics of the development of individual enterprises (Breus, Khaustova, & Denysenko, 2017). Although digitalization offers significant benefits, problems such as high initial costs, the need for a skilled workforce and resistance to change can become an obstacle to the implementation of digitalization in the construction sector.

Thus, the successful functioning of construction enterprises largely depends on understanding the relationship between their life cycle and industry trends, which allows predicting market changes and implementing effective management decisions. The use of the proposed improved mechanism for determining the level of digitalization of the construction sector will contribute to accelerating the processes of state restoration in the post-war period and in the period of post-war reconstruction of Ukraine.

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Section 2.3. Digitalization and UAV Innovations for Sustainable Tourism Development in Post-War Ukraine

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Abstract. *The study explores the transformative potential of digital technologies and unmanned aerial vehicle (UAV) innovations for the reconstruction and sustainable development of Ukraine's tourism sector in the post-war period. Based on a comprehensive assessment of market dynamics, application areas, regional needs, and regulatory conditions, the study identifies significant opportunities for integrating UAVs into heritage preservation, environmental monitoring, memory tourism, and destination management. The analysis demonstrates that Ukraine's rapidly developing UAV industry - characterized by extensive production capacity and advanced technological expertise - constitutes a strategic advantage for civil tourism-oriented applications. At the same time, the research highlights substantial institutional and regulatory barriers, including security-driven airspace restrictions, fragmented data governance, the absence of cross-sectoral platforms, and limited non-military financing. The findings confirm that regional differentiation is essential: liberated territories require UAV solutions for damage assessment and memory tourism, while western regions exhibit greater potential for heritage digitization and ecological tourism. The study proposes a set of strategic priorities to enhance UAV-driven digitalization within the tourism sector, including the development of a national UAV - tourism framework, the creation of public - private funding mechanisms, the establishment of regional innovation hubs, the redirection of industrial UAV output toward civil tourism needs, and the implementation of interoperable cloud and GIS-based data infrastructures. The despite regulatory constraints, UAV technologies offer Ukraine a unique opportunity to accelerate digital transformation and achieve a "leapfrog" effect in tourism recovery. By aligning policy, innovation ecosystems, financial instruments, and data systems, UAVs can become a cornerstone of smarter, safer, and more sustainable post-war tourism development.*

Keywords: *UAVs; tourism recovery; digitalization; post-war development; heritage preservation; environmental monitoring; GIS; Ukraine.*

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1. Conceptualization background. In the wake of the full-scale war in Ukraine, the country's tourism sector faces unprecedented challenges, but also unique opportunities for renewal. Despite the destruction of infrastructure and cultural heritage, recent data show signs of a robust recovery. For instance, domestic tourism has surged by 70% in 2025, compared to the previous year, with over 236,000 Ukrainian travellers using tour-operator services in the summer alone (Vovk, 2025 (1); Travel & Tour World). Moreover, tax revenues from the tourism industry in early 2025 reached UAH 799 million in just the first quarter, marking a 30 % increase compared to the same period in 2024 and exceeding pre-war levels (Visit Ukraine). These trends suggest not just recovery, but a transformation of tourism in Ukraine under wartime- and potentially post-war conditions.

However, rebuilding tourism in a post-war Ukraine is not only a matter of restoring what was, but of reimagining how the sector can be more resilient, sustainable, and digitally enabled. UNESCO estimates that nearly USD 9 billion will be needed over the next decade to reconstruct cultural sites and tourism infrastructure damaged by the war (AP). This enormous reconstruction cost underlines the urgency of innovative approaches.

Against this backdrop, the intersection of digitalization and unmanned aerial vehicles (UAVs) - or drones - presents a promising frontier. The war has accelerated Ukraine's adoption of digital technologies in tourism: virtual tours, augmented reality (AR), secure booking platforms, and gamified experiences are already part of the industry's transformation during war (Chernega, 2022). Meanwhile, UAVs are widely recognized in military and surveillance contexts, but their potential for tourism - especially in a post-war, post-conflict recovery - is understudied.

This chapter examines how digitalization together with UAV innovations can contribute to sustainable tourism development in Ukraine's post-war recovery. It argues that by leveraging drone technologies for mapping, storytelling, heritage preservation, and destination marketing - within a digitally transformed ecosystem - Ukraine can build a more resilient and sustainable tourism sector that not only restores but redefines itself.

To frame our analysis, we draw on three key conceptual pillars:

1) Digitalization in Tourism. Digital transformation in tourism refers to the integration of digital technologies - such as mobile platforms, cloud services, AI, AR/VR, and data analytics - into the tourism value chain: from planning and booking to experience delivery and feedback. In Ukraine,

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digitalization has accelerated during the war, as tour operators, accommodations, and destinations adopt contactless services, virtual tours, and reputation management tools (Chernega, 2022; Haponenko et al., 2022). According to Boiko et al., the use of AI for route planning and chatbots, as well as AR in hotels, has grown significantly: digital tech adoption among Ukrainian tour operators and hotel chains increased by 72.2% in one year (Boiko et al., 2022).

2) UAV (Drone) Technologies. Unmanned Aerial Vehicles (UAVs) or drones have traditionally been associated with military, surveillance, and logistical applications. However, in tourism, they offer novel functions: aerial video for destination marketing, digital heritage documentation, environmental monitoring, and even guiding tourist experiences (e.g., drone-assisted tours). In the Ukrainian context, there is a strong domestic UAV industry (for example, reconnaissance drones developed by local firms) that could be repurposed for civilian use in tourism. Furthermore, UAVs connected to advanced communication networks (e.g., 5G) can support real-time data transmission, high-resolution mapping, and interactive experiences (Mishra & Natalizio, 2020).

3) Sustainable Tourism & Post-War Recovery. Sustainable tourism emphasizes not only economic viability but also environmental responsibility, social inclusivity, and cultural preservation. In a post-war Ukraine, sustainability has a special dimension: rebuilding must balance restoration with innovation, ensuring that tourism contributes to long-term resilience. Research on Ukraine's post-war tourism recovery highlights the need for strategic digital transformation, safe communication channels, and virtual tourism as a complement or substitute for physical travel in de-occupied or fragile territories (Dekhtyar, 2024). Moreover, institutional recovery strategies identify digital infrastructure and innovation as key factors influencing the European vector of tourism development (Olshanska et al., 2024).

Why Digital + UAV Matters for Tourism Recovery in Ukraine:

Narrative and Heritage Preservation: drones can document war-affected heritage sites (ruined buildings, monuments) from the air, supporting digital archives, virtual tours, and storytelling that can attract both domestic and international tourists interested in history, memory, and resilience.

Innovative Destination Marketing: high-quality drone footage can rebrand war-impacted regions as places of recovery and hope, creating new "resilience routes" for dark tourism, memorial tourism, or cultural tourism.

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Sustainable Management: UAVs can support environmental monitoring of natural tourism areas (e.g., national parks), helping manage visitor flows, track ecological recovery, and minimize human impact.

Digital Infrastructure Synergy: when integrated into a broader digital ecosystem - booking platforms, mobile apps, AR experiences - drone-based content can enhance visitor engagement, safety, and planning.

Economic Resilience: investing in drone-tourism can diversify the income streams for local communities and tech firms, helping to rebuild the tourism economy with innovation at its core.

UAV Technologies within the Framework of Technological Innovation Diffusion. The integration of unmanned aerial vehicles (UAVs) into tourism development can be explained through classic innovation adoption theories, most prominently Rogers' Diffusion of Innovations framework. Rogers (2003) argues that the adoption of any technology is driven by its relative advantage, compatibility, complexity, trialability, and observability. These criteria strongly apply to UAVs in post-war Ukraine, where drones provide rapid spatial evaluation, support cultural heritage monitoring, and capture high-quality visual content essential for rebuilding destination image and informing strategic planning (Rogers, 2003).

In parallel, the Technology Acceptance Model (TAM) by Davis (1989) emphasizes perceived usefulness and perceived ease of use as the key determinants of technology adoption (Davis, 1989). In the Ukrainian post-war context, perceived usefulness increases due to UAVs' capacity to reduce fieldwork costs, enhance safety, and enable fast environmental assessments, while perceived ease of use is associated with the availability of intuitive drone software and expanding digital competencies among tourism professionals.

UAVs relevant to tourism can be grouped into several functional categories, each serving a distinct operational purpose (Giones & Brem, 2017). Table 2.9 summarizes UAV types used across tourism domains.

The diffusion of UAVs is also shaped by institutional and regulatory settings. Research in tourism innovation shows that regulatory clarity significantly accelerates digital technology adoption (Gretzel et al., 2015). In Ukraine, airspace restrictions linked to national security intersect with increasing demand for advanced digital tools to rebuild destinations, creating a unique environment where UAV adoption is both highly needed and tightly controlled.

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Table 2.9. Classification of UAV Types for Tourism Applications

UAV Type	Functional Characteristics	Tourism-Related Applications
Multi-rotor UAVs	High maneuverability; stable hovering	Photography, cinematography, cultural heritage inspection
Fixed-wing UAVs	Long endurance; broad coverage area	Landscape mapping, monitoring protected areas
Hybrid VTOL UAVs	Long-distance flight + vertical takeoff	Trail monitoring, surveying large territories
Heavy-lift UAVs	High payload capacity	Supplying equipment to remote eco-zones
Micro-UAVs	Small size; low noise	Indoor heritage scanning, archaeology

Source: created by authors

The drivers and barriers affecting UAV adoption are presented in Table 2.10.

Table 2.10. Drivers and Barriers of UAV Adoption in Tourism

Category	Drivers	Barriers
Technological	Precision data; automation; improved safety	Weather vulnerability; maintenance complexity
Economic	Reduced inspection costs; efficient reconstruction assessments	High upfront investment; training costs
Institutional	Standardization potential; smart destination agendas	Airspace restrictions; regulatory ambiguity
Socio-cultural	Enhanced visitor experience; storytelling	Privacy concerns; low trust in surveillance technologies

Source: created by authors

Table 2.10 highlights that the adoption of UAV technologies in tourism is shaped by a combination of technological, economic, institutional, and socio-cultural factors. Key drivers include the high precision and efficiency of UAV-generated data, reduced operational costs for monitoring and reconstruction activities, opportunities for standardizing destination management processes, and the ability to enhance visitor experiences through improved storytelling and visualization. At the same time, significant barriers remain: technical limitations such as weather sensitivity and maintenance needs, high initial investment and training expenses, restrictive or unclear airspace regulations, and public concerns regarding privacy and surveillance. Overall, the table demonstrates that while UAVs offer substantial advantages for post-war tourism development, their successful integration requires addressing regulatory, financial, and social challenges to ensure responsible

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and sustainable use.

Theoretical Foundations of Sustainable Tourism in Post-Conflict Territories. Sustainable tourism theory, developed by Bramwell and Lane (1993), conceptualizes sustainability as the equilibrium between environmental integrity, socio-cultural preservation, and economic viability. In post-war contexts, sustainability is further shaped by the challenges of destroyed infrastructure, displaced populations, and the need to restore public trust.

Post-conflict tourism studies emphasize that war-affected destinations undergo complex transitions involving reconstruction, identity renegotiation, and narrative reframing (Causevic & Lynch, 2011). Ukraine fits this trajectory as regions affected by the Russian invasion are gradually restoring cultural assets, reopening natural attractions, and rebuilding tourism infrastructure within a broader national recovery agenda.

Resilience theory provides an additional conceptual lens. Holling (1973) defines resilience as the capacity of systems to absorb disturbances and reorganize without losing functional integrity (Holling, 1973). In tourism, resilience refers to the ability of destinations to restore supply chains, reestablish visitor flows, and rebuild institutional governance. UAV technologies strengthen resilience by enabling evidence-based decision-making, rapid environmental assessment, and transparent documentation of reconstruction progress (Becken & Khazai, 2017). The interplay between sustainability principles and post-conflict recovery needs is summarized in Table 2.11.

Table 2.11. Intersection of Sustainability Principles and Post-Conflict Tourism Needs

Sustainability Principle	Post-Conflict Need	UAV Contribution
Environmental protection	Landscape recovery assessment	High-resolution mapping; ecological monitoring
Socio-cultural continuity	Heritage restoration	3D scanning; structural analysis
Economic viability	Restoring tourism revenues	Visual marketing; risk mitigation
Governance transparency	Fair allocation of resources	Objective data; open spatial records

Source: created by authors

In light of the above, let's move on to UAV-Driven Digitalization for Sustainable Post-War Tourism.

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Conceptual Integration: UAV-Driven Digitalization for Sustainable Post-War Tourism. The integration of UAV technologies into digitalized tourism management is supported by research on smart destinations and data-driven governance. Buhalis and Amaranggana (2015) argue that digitalization transforms destinations into interconnected ecosystems powered by real-time data flows. UAVs function as critical data-generating instruments within this system, providing imagery, 3D models, geospatial updates, and environmental observations necessary for destination recovery.

1. Digitalization as an enabler of knowledge-intensive management.

Digital transformation in tourism provides the analytical infrastructure for interpreting UAV-derived data. Studies highlight that GIS platforms, AI tools, and spatial decision-support systems enhance planning accuracy and reduce reconstruction inefficiencies (Xiang et al., 2015).

2. UAV innovations as operational tools for sustainable recovery.

UAVs support sustainable rebuilding through remote monitoring, hazard detection, and reduced environmental disturbance. This aligns with the principles of regenerative tourism (Bellato et al., 2022), which highlights the need for technologies that minimize ecological impact during reconstruction.

3. Sustainability as a strategic framework.

Sustainability ensures that technological adoption remains community-oriented, ethical, and aligned with long-term resilience. Integrating UAVs into this framework supports inclusive governance and strengthens local participation in reconstruction planning (Dredge & Gyimóthy, 2015).

Building on the integrative theoretical foundations outlined above, it becomes evident that digitalization, UAV technologies, and sustainability mechanisms operate not as isolated components but as mutually reinforcing pillars of post-war tourism recovery. The interaction among these domains creates a coherent system in which digital infrastructures enable advanced data processing, UAVs serve as dynamic information generators, and sustainability principles guide strategic decision-making.

To illustrate how these elements function collectively and influence each stage of destination regeneration, this section introduces a conceptual model (Figure 2.4). This model synthesizes the theoretical insights into a unified framework that explains the pathways through which UAV-driven digitalization contributes to sustainable tourism development in post-war Ukraine.

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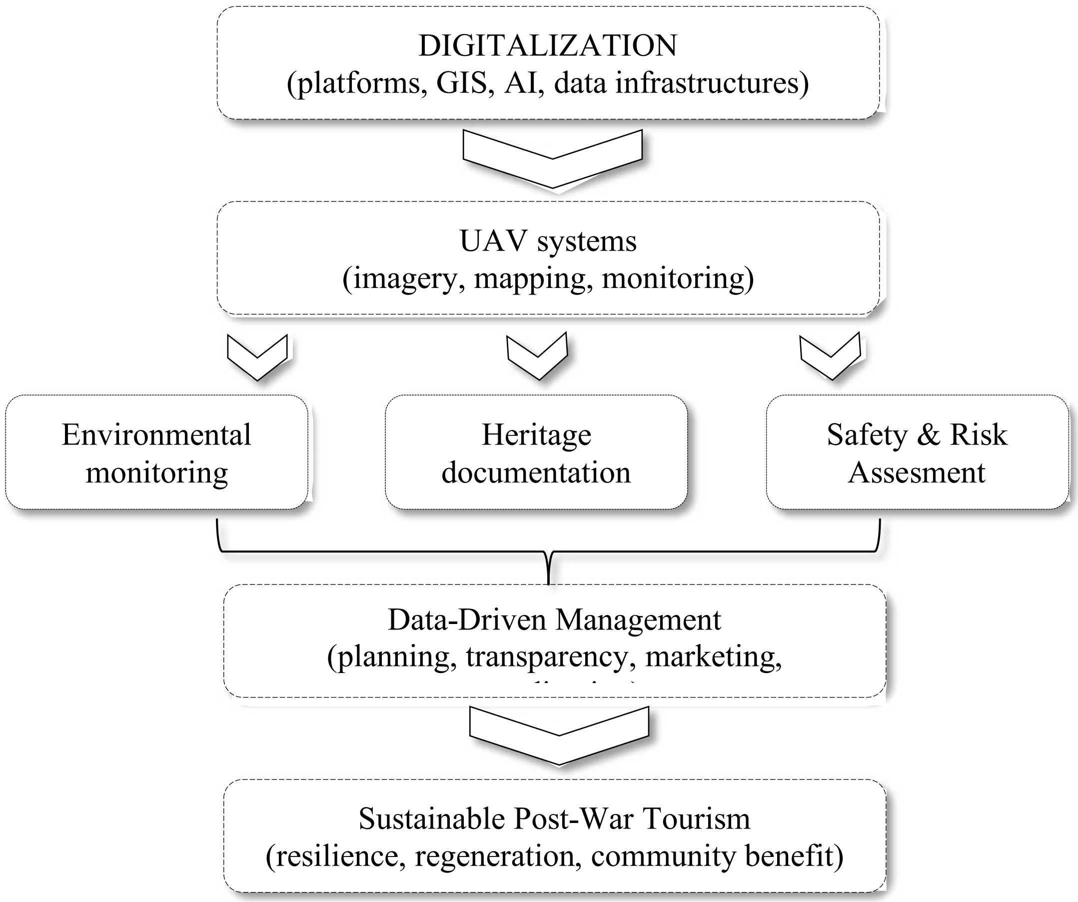

Figure 2.4. Conceptual Model of UAV-Driven Digitalization for Sustainable Post-War Tourism

Source: created by authors

The conceptual model demonstrates the multi-layered process through which UAV technologies enhance data-driven tourism governance. At the input level, digital infrastructures and UAV capabilities form the technological foundation for reliable and continuous data collection. Through operational processes such as environmental monitoring, cultural heritage documentation, and risk assessment, UAVs enable more efficient, transparent, and evidence-based management practices. These processes converge in a central decision-making layer where spatial data, analytical tools, and stakeholder coordination support strategic planning. Ultimately, this system leads to sustainable post-war tourism outcomes by strengthening destination resilience, fostering community-centered development, and ensuring that reconstruction efforts

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align with long-term ecological and socio-cultural priorities.

The conceptual model presented above provides a structured theoretical foundation for understanding how UAV-driven digitalization can support sustainable tourism recovery in post-war Ukraine. However, to evaluate the practical relevance and applicability of these theoretical assumptions, it is necessary to complement the conceptual insights with empirical and contextual analysis. A thorough analytical examination allows us to identify the current state of UAV adoption, assess regional disparities, explore institutional and infrastructural constraints, and understand how digital transformation processes unfold across different segments of Ukraine's tourism sector.

Therefore, the following analytical section builds upon the theoretical propositions by examining real-world conditions, recent developments, and sectoral dynamics that shape the integration of UAV technologies into tourism management. This approach enables a more comprehensive understanding of opportunities, challenges, and priorities for implementing UAV-supported digitalization strategies in the post-war recovery period.

2. Analytical Section: UAV-Driven Digitalization in Ukraine's Post-War Tourism Sector. The Ukrainian drone industry has expanded at an unprecedented rate in recent years. According to a report by StateWatch cited by Interfax-Ukraine, domestic UAV production reached 1.7 million units in 2024, up from only 1,200 in 2022 (Interfax, 2025).

A detailed analysis by Murray Lab confirms that by the end of 2024, the annual production capacity exceeded 4 million UAVs, significantly outpacing initial projections set at the start of the year (Ostafiichuck, D. et al., 2025). This surge is backed by substantial state funding: the Ukrainian Ministry of Defence allocated UAH 104.2 billion for drone procurement over 2024 - 2025, working with more than 70 UAV manufacturers (Ministry of Defence of Ukraine, 2025).

This scale-up does not only reflect military demand. As domestic UAV manufacturers proliferate, the potential spillover into civilian applications - including tourism - is growing. These dynamics lay a strong foundation for deploying UAV technologies beyond defense, toward sustainable tourism and heritage reconstruction (Table 2.12).

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ISBN 978-9916-9320-3-2 (pdf)

Table 2.12. Production & Procurement Metrics for Ukrainian UAV Industry

Metric	Value / Trend	Relevance to Tourism
UAV production in 2024	~ 1.7 million units	Strong industrial supply base
Annual capacity by end 2024	~ 4 million units	Potential for civil orders
State spending (2024 - 2025)	UAH 104.2 billion	Demonstrates institutional commitment

Source: created by authors based on (Interfax, Ostafiichuck, D., Ministry of Defence of Ukraine)

The economic environment for UAV producers is increasingly favorable. In 2024 the drone sector's revenue hit UAH 99 billion, with the government abolishing VAT on key components and providing compensation to manufacturers covering up to 80% of their project costs (Ostafiichuck, Y., 2025). Moreover, a Finway analysis (Vovk, 2025 (2)) notes that over 500 UAV companies are active in Ukraine, producing more than 1,000 different drone models. The country's annual UAV production capacity is now estimated at over 4 million units, driven by both strategic procurement and R&D grants (Cheplyk, 2025).

These enablers - state procurement, fiscal incentives, and a growing industrial base - create a fertile institutional environment for UAV adoption in non-military sectors such as tourism.

UAV Applications in Tourism: Current and Potential Uses. In regions affected by conflict, UAVs are increasingly used by cultural institutions and local restoration projects for documentation of damaged monuments. These drones conduct photogrammetric surveys of churches, forts, and historical sites, building 3D models that can support both reconstruction and virtual heritage experiences. Although systematic tourism-focused deployment is still in the early stages, pilot initiatives reflect a growing recognition of the long-term value of UAV-derived heritage data.

In Ukraine's natural tourist regions - such as the Carpathians or Polissia - environmental agencies use drones for forest health assessments, land-use monitoring, and mapping of tourist trails. While these activities are not (yet) branded as tourism projects, they establish critical infrastructure for future smart ecotourism: UAVs generate high-resolution spatial data that can guide sustainable trail planning, visitor management, and ecological restoration.

Tourism boards and local governments are exploring UAV-based marketing campaigns to reshape the narrative of post-war recovery. Aerial cinematography can become a powerful storytelling tool to project images of resilience, regeneration, and cultural revival. These visual narratives are particularly compelling for "recovery tourism" or memory/pilgrimage tourism, where the story of place matters as much as the physical sites.

Despite the potential, several key gaps remain:

- regulatory uncertainty: many Ukrainian regions still restrict UAV flights due to security concerns, particularly in or near former conflict zones;
- lack of technical specialization: tourism professionals often lack training in drone data collection and analysis;
- data infrastructure: there are few standardized platforms to store, share, and analyze UAV-generated spatial datasets for tourism;
- funding for civil projects: while military procurement is huge, financial mechanisms to support tourism-oriented UAV projects are underdeveloped.

Regional Variations and Strategic Opportunities. Ukraine's regional diversity plays a large role in determining where UAV-enabled tourism recovery can be most effective. Below is a regional breakdown with opportunities and constraints.

Table 2.13. Regional Potential for UAV-Tourism Recovery

Region	Key Opportunities	Main Risks / Barriers
Western Ukraine	Heritage digitization, ecotour routes, marketing	Regulatory delays, local capacity
Central Ukraine	Urban tourism planning, 3D documentation	Limited deconflicted airspace, funding
South / East	Reconstruction mapping, safety monitoring	Security risk, infrastructure damage
Frontline / Liberated	Memory tourism, risk assessment	Demining, regulation, community trust

Source: created by authors

Western Ukraine (Lviv, Zakarpattia, Ivano-Frankivsk): Stable security and highly digitalized local governments make it ideal for UAV-supported heritage tourism, ecotourism, and marketing of recovery narratives.

Central Ukraine (Kyiv, Vinnytsia): Well-connected digitally, potentially good for urban tourism planning, 3D scanning of monuments, and data-based destination management.

Southern/Eastern Ukraine (Odesa, Dnipro, Kharkiv): High reconstruction needs; drone mapping can guide rebuilding, monitor coastal and river regions, and support safety.

Frontline and Liberated Territories: Greatest need for UAVs in

https://doi.org/10.36690/CIDI-EME
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surveying war damage, conducting safety risk assessments, and constructing memory tourism routes - but operationalization depends on demining, regulatory clearance, and community engagement.

Institutional and Regulatory Risks. Deploying UAVs for tourism in a post-war environment demands robust governance frameworks. Key risks include:

- *airspace management*: Current restrictions, driven by national security, limit civilian flight;
- *data security and privacy*: UAVs collect sensitive spatial data; without regulation, there is risk of misuse or breach (Mekdad et al., 2023);
- *cybersecurity*: UAV networks are vulnerable to attacks. Cybersecurity frameworks must be established to protect drone operations and data integrity;
- *standardization and certification*: There is a need for certification standards for UAV operations, especially for tourism-specific tasks.

If not addressed, these risks could significantly slow down the adoption of UAV-driven digital tools in tourism.

3. Recommendations for Strategic Action. The integration of UAV-driven digital technologies into Ukraine's post-war tourism sector requires a coordinated, multi-layered strategy. While Ukraine possesses exceptional technological capacity and dynamic market growth, the transition from defense-oriented UAV use to civilian and tourism-oriented applications is neither automatic nor guaranteed. To ensure that UAVs become a meaningful catalyst for sustainable tourism recovery, it is essential to develop a coherent policy, institutional, infrastructural, and community-based framework. The following recommendations outline a comprehensive pathway for action across national, regional, and local levels, emphasizing the importance of regulatory modernization, capacity-building, financial instruments, knowledge systems, inter-institutional coordination, and long-term sustainability planning.

1. Establish a National UAV - Tourism Integration Framework. A foundational strategic step is the creation of a national-level framework that articulates the vision, principles, standards, and governance mechanisms for UAV application in tourism. This framework should serve as an umbrella policy guiding all subsequent operational decisions and investments. It would help synchronize the roles of ministries, regional governments, digital agencies, cultural institutions, environmental bodies, and private UAV operators.

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ISBN 978-9916-9320-3-2 (pdf)

Key elements of the framework:

1. Regulatory modernization roadmap:

– A plan for gradually liberalizing civilian UAV operations in deconflicted regions;
– Clear zones of permitted, restricted, and prohibited drone usage;
– Standardized procedures for obtaining flight permissions for tourism projects;
– Mechanisms for rapid risk assessment in heritage sites, natural parks, and urban tourist zones.

2. Legal and ethical principles:

– Privacy protection and ethical aerial data collection guidelines;
– Cultural sensitivity norms for filming sacred, memorial, or conflict-affected sites;
– Data-security protocols to ensure secure storage of drone-collected information.

3. Technical standards and certification:

– Requirements for UAV types, sensors, and data formats used for heritage digitalization, environmental monitoring, and tourism mapping;
– Certification programs for UAV operators specializing in tourism, cultural heritage, and environmental applications;
– Minimum documentation criteria for spatial data incorporated into government planning.

4. Public communication strategy:

– Information campaigns to build trust in UAV usage;
– Educational materials explaining how aerial data supports safety, sustainability, and transparency;
– Community engagement mechanisms in regions where UAV operations may raise social sensitivity.

By establishing this framework, Ukraine can institutionalize UAV-enabled tourism as a structured and regulated component of post-war reconstruction.

2. Create a Dedicated Public - Private Fund for UAV-Based Tourism Projects. The lack of targeted financial mechanisms is a major barrier to civilian UAV adoption. Despite large-scale military investments, few funding instruments support the use of drones in heritage preservation, environmental monitoring, or tourism development. To address this gap, a **public - private**

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UAV Tourism Innovation Fund should be established.

2.1. Priority funding directions:

1. Heritage documentation and reconstruction projects:

– Financing aerial surveys of destroyed or at-risk monuments;
– Supporting 3D modelling and digital twins of cultural heritage;
– Creating immersive VR tourism experiences using UAV imagery.

2. Environmental sustainability and ecotourism:

– Supporting UAV-based monitoring of national parks and biosphere reserves;
– Financing mapping of hiking trails, recreational zones, and ecological risks;
– Developing UAV-assisted biodiversity monitoring programs in tourism areas.

3. Destination marketing and storytelling:

– Funding professional UAV-based promotional videos for regions undergoing recovery;
– Creating narrative-driven aerial campaigns focused on cultural resilience, landscapes, and reconstruction.

4. Safety-oriented UAV solutions:

– Supporting UAV-based demining surveys (in coordination with specialized agencies);
– Aerial scans for infrastructure stability assessment in liberated territories.

2.2. Mechanism and governance:

– The fund should operate through multi-source financing: state contributions, regional co-funding, private investment, diaspora contributions, and grants from UNESCO, UNDP, or EU recovery programs.
– Priority should be given to pilot regions, where a concentrated investment can yield demonstrable results and scalable models.
– An independent advisory board of UAV experts, tourism specialists, heritage scholars, and local authorities should oversee project selection.

3. Develop Regional UAV Innovation Hubs Focused on Tourism and Heritage. Given the strong regional diversity in Ukraine, a decentralized approach is essential. Regional UAV hubs would function as centers of excellence that pool equipment, skills, and stakeholders, thereby enabling cross-institutional collaboration.

3.1. Functions of regional hubs:

1. Technical services and training:

– Offering certified UAV operator training tailored for tourism workers, heritage conservators, municipal planners, and environmental rangers;
– Providing access to specialized drones (LiDAR-equipped, photogrammetry drones, thermal cameras).

2. Data processing and GIS competence centers:
– Supporting local authorities with processing UAV imagery into usable forms such as 3D models, heat maps, orthoimages, or digital terrain visualizations;
– Ensuring interoperability with regional and national GIS platforms.

3. Pilot project testing. Enabling regions to prototype UAV-solutions: e.g., aerial visitor flow modelling, eco-trail mapping, coastal erosion monitoring, or damage assessment.

4. Knowledge dissemination:
– Hosting conferences, workshops, and hackathons bringing together UAV engineers, tourism boards, universities, and NGOs;
– Creating open-access repositories of regional UAV datasets.

3.2. Suggested regional distribution
– Western Hub (Lviv / Ivano-Frankivsk): Smart heritage tourism, ecotourism, cross-border cooperation.
– Central Hub (Kyiv / Vinnytsia): Urban digital twins, infrastructure monitoring, heritage 3D digitization.
– Southern Hub (Odesa / Mykolaiv): Coastal tourism planning, environmental monitoring, erosion mapping.
– Eastern & Liberated Territories Hub (Dnipro / Kharkiv / Kherson regions): Damage assessment, memory tourism planning, safety risk monitoring.

Such hubs ensure that technological capacity is evenly distributed and regionally contextualized.

4. Integrate UAV Technologies into National and Regional Digital Tourism Platforms. To maximize the value of UAV-collected data, Ukraine must develop digital ecosystems that allow stakeholders to store, access, interpret, and share aerial information. Without such platforms, large-scale drone data remains underutilized.

4.1. Recommended platform components:

1. National Geoportal for Tourism and Heritage
– Hosting standardized UAV datasets;
– Displaying 3D models of cultural monuments;

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– Providing interactive maps of tourist routes, reconstructed sites, and risk zones.

2. Regional GIS dashboards. Allowing local authorities to plan infrastructure, manage visitor flows, and integrate aerial data into zoning and land-use planning decisions.

3. Interoperability with EU platforms

– Ensuring compatibility with INSPIRE standards for geospatial information;

– Facilitating cross-border tourism cooperation in the Carpathian region.

4. Open Data Policy

– Providing publicly accessible datasets for researchers, entrepreneurs, and communities, with sensitive information appropriately restricted.

– Digital platforms should be accompanied by capacity-building programs to ensure that municipalities and tourism boards can interpret technical data and translate it into planning decisions.

5. Build Human Capital: Training, Certification, and Academic Integration. Human resource development is a critical precondition for sustaining UAV-enabled tourism solutions. Despite strong military experience with UAV operation, tourism professionals, municipal staff, and heritage workers require dedicated training programs.

5.1. Key human capital interventions

1. Certification Programs for UAV Operators in Tourism. Specialization tracks: heritage documentation, environmental monitoring, destination mapping, crisis assessment.

2. University-Level Training Modules:

– Implementing courses in tourism programs that cover drone photogrammetry, digital storytelling, and GIS analysis;

– Encouraging joint degree programs between tourism departments and engineering faculties.

3. Professional Requalification Programs. Targeting displaced communities, demobilized veterans, and unemployed youth with training in UAV tourism services.

4. Local Community Workshops:

– Raising awareness about ethical UAV usage;

– Encouraging communities to participate in co-creation of aerial heritage archives and ecotourism maps.

By embedding UAV expertise into educational and professional systems,

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ISBN 978-9916-9320-3-2 (pdf)

Ukraine can ensure long-term sustainability and local ownership of UAV-driven tourism recovery.

6. Strengthen Regulatory and Data-Governance Mechanisms for Safe UAV Use. Given the sensitive nature of aerial data - especially in post-war contexts - Ukraine must adopt clear and robust governance mechanisms.

6.1. Priority actions:

1. Risk-Based Airspace Management:

– Implementing a layered flight-permission system for tourism drones;
– Coordinated deconfliction across agencies such as the State Aviation Service, Ministry of Digital Transformation, and the Ministry of Culture.

2. Data Privacy and Ethical Use Guidelines:

– Protecting private households during aerial filming;
– Clear obligations for anonymizing or blurring sensitive footage.

3. Cybersecurity Protocols

– Mandatory encryption for UAV control systems;
– Secure cloud storage for UAV-derived spatial datasets.

4. Liability and Insurance Framework

– Defining insurance requirements for professional tourism UAV operators;
– Introducing mandatory compliance audits for large-scale aerial projects.

Robust governance ensures public trust and prevents the misuse of UAV technologies.

7. Promote International Collaboration and Transfer of Best Practices. Ukraine should integrate its UAV tourism strategies into broader European and global initiatives.

7.1. Key strategic partnerships

1. UNESCO and ICCROM. For UAV-based heritage preservation, damage assessment, and digital archives.

2. EU Tourism Digitalization Programs. For knowledge exchange on smart tourism, digital twins, and visitor analytics.

3. Regional cross-border partnerships. Particularly in the Carpathian Euroregion, enabling transboundary ecotourism routes mapped through UAV technologies.

4. Academic Consortia. Joint research projects focusing on UAV applications in sustainable tourism, memory tourism, and landscape restoration.

International cooperation accelerates knowledge transfer and attracts

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funding for innovative tourism recovery projects.

8. Mobilize UAVs as Drivers of Sustainable and Community-Based Tourism. Tourism recovery should prioritize sustainability and community resilience. UAVs can support this by enabling inclusive planning, monitoring, and storytelling.

8.1. Community-centered interventions:

1. Participatory Mapping Using UAVs. Engaging local communities in identifying and mapping cultural assets, ecological sites, and memory landscapes.

2. Co-Creation of Heritage Narratives. UAV imagery can help communities document their stories of loss, resilience, and renewal.

3. Ecological Monitoring by Local Stakeholders. Training community members to use UAVs to monitor forests, rivers, and wildlife in tourism zones.

4. Inclusive Benefit-Sharing Models. Ensuring profits from UAV-based tourism services (e.g., guided drone tours, aerial photography) support local communities.

This approach ensures that tourism recovery strengthens social cohesion and enhances livelihood opportunities in post-war regions.

The adoption of UAV technologies for sustainable tourism development in post-war Ukraine requires a holistic strategy. Strategic recommendations include establishing a national UAV - tourism framework, developing targeted funding mechanisms, creating regional innovation hubs, building digital platforms, enhancing human capital, strengthening regulatory governance, fostering international collaboration, and promoting community-centered sustainability models. Collectively, these actions create an integrated policy, institutional, and technological environment that supports the responsible, efficient, and transformative use of UAVs in rebuilding Ukraine's tourism sector.

Conclusions. Bringing together the market, application, regional, and regulatory analysis, several key insights emerge:

Strong Supply-Side Momentum: The Ukrainian UAV industry is highly developed, with hundreds of companies and millions of units produced. This supply-side strength is a major asset for tourism-focused drone use.

Emerging Civil Use Demand: While demand from tourism is nascent, existing environmental and heritage applications indicate strong latent potential.

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Significant Institutional Barriers: Security-driven airspace regulation, lack of shared platforms, and insufficient non-military funding remain major obstacles.

Regional Strategy is Critical: Different regions require tailored UAV-tourism strategies - from memory tourism in liberated zones to heritage digitization in the west.

Opportunity for Digital Tourism Leap: UAVs offer a catalyst not only for reconstruction but for digital leapfrogging in Ukraine's tourism sector, leveraging high-tech capacity to rebuild smarter, safer, and more sustainably.

Based on the analysis, the following strategic priorities emerge for integrating UAV-driven digitalization into Ukraine's tourism recovery:

1. develop a national UAV-tourism framework that aligns airspace regulation, data governance, and tourism policy;
2. establish a public-private fund to subsidize UAV-based tourism pilot projects - especially in heritage, environmental and memory tourism;
3. create regional innovation hubs that combine drone operators, tourism boards, and community organizations to co-design digital tourism solutions;
4. capitalize on existing production capacity by channeling some of the UAV industrial output into civil contracts for heritage and ecotourism;
5. implement data infrastructure (cloud platforms, GIS portals) to store, analyze, and share UAV-collected data among stakeholders.

In summary, Ukraine's strong UAV manufacturing capacity, emerging civil-sector demand, and diverse regional tourism needs create a unique opportunity for a technology-driven recovery of the tourism sector. Despite regulatory and institutional obstacles, UAVs can enable a digital leap in heritage preservation, environmental monitoring, and destination development. To fully realize this potential, Ukraine must align national policy, regional innovation, funding mechanisms, and data infrastructure into a coherent, future-oriented UAV - tourism ecosystem.

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Chapter 3
Cross-Cutting Challenges of the Era of Digitalization and AI

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Section 3.1. Socio-Economic Development of Territories under Prolonged External Threats: Structural Disparities and the Role of Digital Transformation: Case of Ukraine

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Abstract*. Territorial socio-economic development under prolonged external threats constitutes a distinct and increasingly prevalent development context, characterized by persistent uncertainty, asymmetric shocks, and cumulative structural effects. In such conditions, traditional territorial development models oriented toward equilibrium growth and convergence prove insufficient. Prolonged external threats - such as military aggression, hybrid warfare, and systemic disruptions - reshape spatial development trajectories, intensify structural disparities, and place exceptional stress on institutional and governance systems. Against this background, digital transformation has emerged as a critical but ambivalent factor influencing territorial resilience and inequality. The aim of this chapter is to theoretically and empirically assess the role of digital transformation in shaping territorial socio-economic development under prolonged external threats, with particular attention to its capacity to enhance territorial resilience and its implications for structural disparities in the Ukrainian context. The theoretical analysis demonstrates that structural disparities function both as outcomes and drivers of territorial vulnerability under prolonged external threats, reinforcing core - periphery dynamics and path dependency. Digital transformation is shown to enhance economic and institutional continuity, thereby strengthening territorial resilience, but only under conditions of adequate digital infrastructure, human capital, and governance capacity. Empirical modeling based on Ukraine-specific indicators suggests that digital transformation operates as a conditional and spatially differentiated driver of development, capable of mitigating territorial decline in some regions while contributing to digital polarization in others. The results indicate that without inclusive, place-based policy interventions, digitalization risks reproducing and intensifying existing territorial inequalities.*

Keywords*. territorial socio-economic development; prolonged external threats; structural disparities; digital transformation; territorial resilience; institutional capacity; digital governance; regional inequality; crisis-driven development; Ukraine*

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1. Territorial Development in an Era of Prolonged External Threats. In the twenty-first century, territorial socio-economic development increasingly unfolds under conditions of prolonged external threats that fundamentally reshape development trajectories. Unlike short-term shocks, such threats are characterized by persistence, cumulative effects, and deep structural consequences. In the Ukrainian context, these threats include military aggression, hybrid warfare, geopolitical instability, global economic turbulence, energy insecurity, and the long-term repercussions of the COVID-19 pandemic.

Military aggression against Ukraine represents not merely a security challenge but a systemic external pressure that affects all dimensions of territorial development. Prolonged hostilities disrupt production networks, destroy infrastructure, alter demographic patterns, and undermine investment confidence. At the same time, hybrid threats - cyberattacks, information warfare, and economic coercion - target institutional capacity and social cohesion, further complicating regional governance (Kuzio, 2022).

The prolonged nature of external threats produces asymmetric impacts across Ukrainian territories. Regions closer to conflict zones experience direct destruction of physical capital, forced displacement of populations, and fiscal stress, while relatively safer regions face indirect pressures through labour inflows, housing shortages, and overstretched public services. As a result, existing interregional disparities are reinforced rather than mitigated.

Empirical evidence indicates that prolonged crises exacerbate deindustrialization trends, weaken small and medium-sized enterprises (SMEs), and intensify informal economic activity (World Bank, 2023). These dynamics challenge traditional regional development models and necessitate new approaches that integrate resilience, adaptability, and digital transformation.

In Ukraine, digital transformation has emerged as a critical structural response to prolonged external threats. Rather than serving solely as a tool for efficiency gains, digitalization increasingly functions as a mechanism for maintaining economic continuity, ensuring access to public services, and supporting institutional resilience. The rapid expansion of e-government platforms, digital public services, and remote economic activities illustrates the strategic role of digital technologies in sustaining territorial development under extreme conditions (OECD, 2022).

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2. Theoretical Framework of Territorial Socio-Economic Development under Crisis Conditions. Territorial socio-economic development is traditionally understood as a multidimensional and spatially embedded process that combines economic growth, social well-being, institutional quality, and spatial cohesion within a defined territory. Unlike sectoral or macroeconomic approaches, territorial development emphasizes the role of local resources, institutional arrangements, and place-specific dynamics in shaping development trajectories (Barca et al., 2012).

In classical regional economics, territorial development was primarily associated with factor endowments, industrial location, and economies of scale. However, contemporary approaches increasingly recognize that development outcomes depend not only on material resources but also on institutional capacity, governance quality, social capital, and innovation ecosystems. This shift is particularly relevant in crisis conditions, where traditional growth drivers are disrupted and adaptive capacity becomes a critical determinant of territorial performance.

For Ukraine, territorial development is shaped by pronounced interregional disparities, historically rooted industrial specialization, and asymmetric access to infrastructure and public services. These structural characteristics significantly condition the ability of territories to respond to prolonged external threats.

Endogenous growth theory emphasizes the role of human capital, knowledge accumulation, innovation, and institutional quality as internal drivers of development (Romer, 1990). In territorial terms, this approach highlights the importance of local entrepreneurship, learning processes, and embedded innovation networks.

Under crisis conditions, however, the mechanisms of endogenous growth are profoundly altered. Prolonged external threats weaken investment incentives, disrupt innovation systems, and constrain labour mobility. As a result, endogenous development potential becomes highly uneven across territories. Regions with diversified economies, strong human capital, and adaptive institutions are better positioned to sustain development, while structurally weaker territories experience cumulative decline.

The place-based development approach extends endogenous growth theory by arguing that development policies must be tailored to territorial specificities rather than applying uniform, place-neutral interventions (Barca et al., 2012). In the Ukrainian context, this implies differentiated policy

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responses for conflict-affected regions, industrial peripheries, rural territories, and metropolitan areas. Crisis conditions reinforce the relevance of place-based strategies, as standardized policy instruments often fail to address asymmetric shocks and localized vulnerabilities.

New economic geography provides a spatial framework for understanding territorial disparities through mechanisms of agglomeration, increasing returns, and market access (Krugman, 1991). According to this perspective, economic activity tends to concentrate in core regions, while peripheral territories face structural disadvantages.

Prolonged external threats amplify core - periphery dynamics. In crisis conditions, capital, skilled labour, and innovation gravitate toward safer and institutionally stronger regions, reinforcing spatial concentration. Peripheral and conflict-affected territories, by contrast, suffer from capital flight, labor outmigration, and infrastructure degradation.

In Ukraine, military aggression and security risks have intensified spatial polarization. Metropolitan regions and relatively secure western territories increasingly function as economic cores, while eastern and frontline regions face long-term developmental setbacks. New economic geography thus provides a critical lens for understanding why territorial disparities persist and deepen under prolonged external threats.

Institutional economics emphasizes that development outcomes are shaped by formal rules, informal norms, and governance structures that coordinate economic activity (North, 1990). Institutions determine transaction costs, investment incentives, and the capacity of territories to mobilize resources.

Crisis conditions place exceptional stress on institutional systems. Regulatory uncertainty, emergency governance, and weakened enforcement mechanisms can undermine institutional credibility. At the same time, crises may trigger institutional innovation, particularly when existing frameworks prove inadequate.

In Ukraine, prolonged external threats have exposed both institutional fragility and institutional adaptability. Decentralization reforms have strengthened local governance capacity, yet disparities in administrative competence and fiscal resources remain significant. Digital institutions - such as e-government platforms - have emerged as critical tools for maintaining institutional continuity and public service provision under crisis conditions.

From an institutional perspective, territorial socio-economic

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development under prolonged threats depends less on static institutional design and more on adaptive capacity, regulatory flexibility, and coordination across governance levels.

Crisis economics conceptualizes prolonged shocks as moments of heightened uncertainty that disrupt established development paths and open windows for structural transformation (Aiginger & Rodrik, 2020). However, such transformations are constrained by path dependency - the tendency of territories to remain locked into existing economic structures due to sunk costs, institutional inertia, and vested interests.

In territorial systems, path dependency is particularly strong in mono-industrial regions and areas with limited innovation capacity. Prolonged external threats may accelerate deindustrialization without generating viable alternative development paths, leading to long-term stagnation.

For Ukraine, crisis-induced transformation has been uneven. While certain sectors - particularly information technology and digital services - have demonstrated resilience and growth, traditional industrial regions face difficulties in reorienting their economic structures. The theoretical framework thus underscores that crisis alone does not guarantee positive transformation; institutional guidance and strategic intervention are essential.

The digital economy introduces a qualitatively new dimension to territorial development theory. Digital infrastructure, platforms, and data-driven governance reduce spatial constraints, enable remote economic participation, and reshape labour markets (Malecki, 2018).

Under crisis conditions, digitalization functions as a resilience mechanism by sustaining economic activity, preserving access to public services, and facilitating coordination across territories. In Ukraine, digital platforms have enabled remote work, digital entrepreneurship, online education, and fintech solutions even in conditions of physical insecurity.

However, the digital economy also generates new forms of territorial inequality. Differences in digital infrastructure, skills, and institutional readiness create a “digital divide” that mirrors and potentially reinforces existing spatial disparities. Consequently, digitalization must be embedded within a broader institutional and territorial development framework rather than treated as a neutral technological process.

Territorial resilience is increasingly understood not as the ability to return to a pre-crisis equilibrium, but as the capacity to absorb shocks, adapt, and maintain functionality. Digital transformation strengthens resilience by

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enabling alternative operational modes and flexible coordination structures.

Synthesizing the above theoretical perspectives, territorial socio-economic development under prolonged external threats can be conceptualized as the outcome of interaction among five key dimensions:

1. Structural economic characteristics (diversification, sectoral composition);
2. Spatial positioning (core - periphery dynamics);
3. Institutional capacity and governance quality;
4. Digital readiness and technological infrastructure;
5. Adaptive potential under crisis conditions.

In the Ukrainian context, prolonged external threats act as an exogenous constraint that reshapes all five dimensions simultaneously. Development outcomes therefore depend not only on initial conditions but also on the ability of institutions to leverage digital transformation, mitigate disparities, and guide structural adaptation.

This integrative theoretical framework provides the analytical foundation for examining how digital transformation can either mitigate or reproduce territorial inequalities under prolonged external threats and informs the design of targeted, place-based development policies.

3. Structural Disparities in Territorial Development under Prolonged Threats. Structural disparities constitute a core feature of territorial socio-economic development, reflecting historically formed differences in economic structures, demographic potential, institutional capacity, and infrastructure provision. Under conditions of prolonged external threats, such disparities tend not only to persist but to deepen, as asymmetric shocks interact with pre-existing vulnerabilities.

In Ukraine, territorial disparities are rooted in the inherited industrial geography of the Soviet period, characterized by heavy industrial concentration in the eastern regions and agricultural specialization in rural and peripheral areas. These structural patterns created uneven resilience to external shocks. Prolonged military aggression has intensified this asymmetry by disproportionately affecting territories with high exposure to physical destruction, security risks, and logistical disruption (World Bank, 2023).

Unlike cyclical downturns, prolonged external threats produce cumulative and path-dependent effects. Regions that lose productive capacity, human capital, or infrastructure face long-term constraints on recovery, even when macroeconomic conditions improve. Structural disparities thus become

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self-reinforcing, limiting convergence and undermining territorial cohesion.

Economic disparities under prolonged external threats manifest primarily through differences in sectoral composition, enterprise structure, and access to capital. Regions dominated by heavy industry and extractive sectors are particularly vulnerable to disruptions in supply chains, energy infrastructure, and export logistics. In Ukraine, industrial territories historically reliant on metallurgy, mining, and large-scale manufacturing have experienced significant output losses and employment contraction.

Small and medium-sized enterprises play a dual role in territorial economies. On the one hand, SMEs provide flexibility and employment, particularly in services and local markets. On the other hand, they face heightened vulnerability under crisis conditions due to limited financial buffers, restricted access to credit, and increased regulatory uncertainty. Prolonged external threats exacerbate these constraints, leading to business closures and informality, especially in peripheral regions (OECD, 2022).

Capital allocation under crisis conditions further reinforces territorial disparities. Investment flows tend to concentrate in safer regions with stronger institutions and better infrastructure, while high-risk territories experience capital flight or investment stagnation. Although digital finance and fintech solutions offer alternative channels for capital access, their territorial impact remains uneven due to disparities in digital readiness and financial literacy.

Social and demographic disparities represent one of the most profound consequences of prolonged external threats. In Ukraine, large-scale internal displacement has reshaped territorial demographics, labour markets, and social infrastructure. Regions hosting internally displaced persons (IDPs) experience population growth and labour supply expansion, while conflict-affected territories face depopulation, aging, and skill erosion (UNDP, 2023).

Human capital polarization emerges as a critical dimension of structural disparity. Skilled and mobile workers are more likely to relocate to economically dynamic or safer territories, while vulnerable populations remain in high-risk regions. This selective migration undermines the long-term development potential of peripheral territories and increases the burden on social services in host regions.

Access to education, healthcare, and social protection also varies significantly across territories. Prolonged external threats disrupt service provision, particularly in rural and frontline areas, reinforcing social inequality and limiting opportunities for upward mobility.

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Spatial inequalities in infrastructure provision constitute a major constraint on territorial development under crisis conditions. Physical infrastructure - transport, energy, housing - suffers direct damage in conflict-affected regions, while maintenance and modernization are often postponed due to fiscal constraints and security risks.

Digital infrastructure introduces an additional layer of spatial inequality. While urban centres and economically dynamic regions benefit from advanced broadband connectivity and digital services, rural and peripheral territories lag behind. This digital divide limits the capacity of digital transformation to function as an equalizing force and instead risks reproducing existing disparities (Malecki, 2018).

In Ukraine, uneven access to digital infrastructure constrains remote work, online education, telemedicine, and digital entrepreneurship in less developed territories. As a result, spatial inequalities increasingly reflect not only physical distance but also digital exclusion.

Institutional capacity varies significantly across territories, shaping their ability to respond to prolonged external threats. Local governments differ in administrative competence, fiscal autonomy, and strategic planning capacity. While decentralization reforms have enhanced local governance in Ukraine, institutional disparities remain pronounced, particularly between large urban centres and small municipalities.

Crisis conditions amplify governance asymmetries. Territories with strong institutions are better equipped to mobilize resources, coordinate stakeholders, and implement adaptive policies. Conversely, institutional weaknesses in peripheral regions limit access to state support and international assistance, reinforcing structural disadvantage (North, 1990).

Digital governance tools partially mitigate institutional disparities by standardizing procedures and improving transparency. However, their effectiveness depends on local administrative capacity and digital skills, which remain unevenly distributed.

Structural disparities and digital transformation interact in complex and often contradictory ways. On the one hand, digital technologies provide opportunities to overcome geographic isolation, diversify economic activity, and enhance service delivery. On the other hand, territories with limited digital infrastructure, skills, or institutional readiness risk exclusion from digital growth processes.

In Ukraine, digital transformation has demonstrated its potential to

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support territorial resilience, particularly through e-government services and digital entrepreneurship. However, without targeted policy interventions, digitalization may reinforce existing inequalities by disproportionately benefiting already advantaged territories.

The persistence of structural disparities under prolonged external threats underscores the need for differentiated, place-based territorial development policies. Uniform policy instruments are insufficient to address asymmetric shocks and heterogeneous territorial conditions. Instead, policy design must integrate economic, social, infrastructural, and institutional dimensions.

For Ukraine, reducing structural disparities requires coordinated investment in digital and physical infrastructure, targeted support for SMEs, human capital development, and institutional capacity building at the local level. Digital transformation should be embedded within a broader territorial strategy aimed at resilience, inclusiveness, and long-term development rather than treated as a standalone technological solution.

4. Institutional Environment and Governance under Prolonged External Threats. In conditions of prolonged external threats, institutions cease to function merely as stabilizing frameworks and instead become dynamic mechanisms of adaptation and survival. Classical institutional economics conceptualizes institutions as constraints that reduce uncertainty and transaction costs (North, 1990). However, under crisis conditions characterized by uncertainty, volatility, and structural breaks, institutional effectiveness depends less on stability and more on adaptive capacity - the ability to modify rules, procedures, and governance practices in response to persistent external pressure.

Territorial resilience under prolonged threats is therefore inseparable from institutional adaptability. Regions with flexible governance structures, professional administrative capacity, and effective coordination mechanisms are better equipped to maintain socio-economic functionality. Conversely, territories with rigid institutional arrangements experience governance paralysis, delayed responses, and ineffective policy implementation.

In Ukraine, prolonged military aggression has revealed a differentiated institutional landscape. Some local governments have demonstrated high adaptive capacity - rapidly reallocating resources, coordinating humanitarian and economic responses, and integrating digital tools - while others have struggled to perform basic administrative functions. This divergence highlights that institutional disparities constitute not only a consequence but

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also a driver of uneven territorial development.

Prolonged external threats fundamentally alter the logic of multilevel governance. In stable conditions, decentralization enhances efficiency and responsiveness by aligning decision-making with local needs. Under crisis conditions, however, decentralization introduces coordination risks, particularly when threats are systemic and territorially asymmetric.

Ukraine’s decentralization reform has significantly expanded the competencies of local governments in areas such as budget management, service provision, and local development planning. Yet prolonged external threats have increased dependence on central coordination for security, infrastructure restoration, macroeconomic stabilization, and international aid management.

This creates a structural tension between:

- centralized crisis coordination, which enhances speed and strategic coherence; and
- decentralized territorial governance, which enables contextualized and inclusive responses.

Empirical evidence from crisis governance suggests that neither extreme centralization nor full decentralization is effective under prolonged threats. Instead, adaptive multilevel governance models - characterized by vertical coordination, horizontal learning, and flexible role allocation - are required. In Ukraine, governance effectiveness increasingly depends on the capacity to dynamically reconfigure responsibilities between governance levels in response to evolving threats.

Fiscal institutions represent a critical transmission channel through which prolonged external threats translate into territorial inequality. Crisis conditions reduce national fiscal space while simultaneously increasing expenditure needs related to defence, social protection, and reconstruction. This creates structural trade-offs that disproportionately affect territorially differentiated development spending.

Local fiscal capacity in Ukraine remains highly uneven, reflecting disparities in economic structure, population density, and tax bases. Under prolonged threats, these disparities are magnified by asymmetric shocks: territories directly affected by destruction face increased expenditure needs but declining revenue capacity, while safer regions may experience revenue growth alongside infrastructure and service overload.

From a political economy perspective, fiscal equalization mechanisms

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under crisis conditions face three structural limitations:

1. Temporal mismatch between urgent needs and delayed transfers;
2. Information asymmetry regarding territorial damage and recovery capacity;
3. Political prioritization of short-term stabilization over long-term development.

Digital public finance tools - such as real-time budget monitoring and data-driven allocation models - offer partial solutions but cannot substitute for structural reform of fiscal institutions. Without institutional redesign, fiscal governance risks entrenching territorial inequality rather than mitigating it.

Prolonged external threats require regulatory systems to operate under conditions of radical uncertainty. Traditional regulatory models - designed for predictability and incremental change - are poorly suited to crisis environments characterized by rapid shifts and incomplete information.

In Ukraine, crisis-induced regulatory flexibility has included simplified licensing, emergency procurement procedures, and accelerated digitalization of administrative processes. These measures have reduced transaction costs and supported business continuity, particularly in digitally enabled sectors. However, prolonged regulatory flexibility entails significant risks, such as erosion of legal certainty; weakening of accountability mechanisms; increased exposure to corruption and regulatory capture.

Institutional theory suggests that crisis governance must distinguish between temporary regulatory deviation and institutionalized reform. Failure to codify and normalize effective crisis-induced innovations risks either permanent institutional degradation or reversion to inefficient pre-crisis frameworks. Digital governance under prolonged external threats should be conceptualized as institutional infrastructure, not as a technological add-on. Digital public platforms redefine the interface between state, business, and citizens, altering power relations, accountability mechanisms, and territorial governance capacity. In Ukraine, digital governance systems have ensured continuity of public administration under conditions of displacement, infrastructure damage, and security constraints. They have also reduced discretionary behaviour, increased transparency, and facilitated inter-territorial coordination.

Nevertheless, digital governance introduces new institutional asymmetries when territories with higher digital capacity gain governance advantages; digitally excluded communities face compounded

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ISBN 978-9916-9320-3-2 (pdf)

marginalization and local administrations with limited digital skills struggle to utilize digital tools effectively.

Thus, digital governance simultaneously functions as a mechanism of institutional convergence and divergence. Its territorial impact depends on complementary investments in human capital, organizational change, and regulatory adaptation. Under prolonged external threats, national territorial governance becomes embedded within international institutional frameworks. Financial assistance, reconstruction funding, and technical cooperation introduce external governance logics that influence domestic institutional evolution. In Ukraine, international conditionality has supported transparency, digitalization, and institutional reform. However, conditional governance may also constrain territorial policy autonomy by prioritizing standardized frameworks over place-based adaptation.

From a theoretical standpoint, international institutional embeddedness is most effective when it strengthens endogenous institutional capacity; enhances multilevel governance coordination; supports territorially differentiated development strategies. Over-reliance on external governance mechanisms risks creating institutional dependency and weakening domestic policy ownership.

Prolonged external threats increase the risk of institutional traps - self-reinforcing governance failures that persist despite reform efforts. These include emergency governance trap, where temporary measures become permanent; centralization trap, undermining local initiative; digital elitism trap, benefiting only digitally advanced territories.

Avoiding such traps requires deliberate institutional design that integrates crisis responsiveness with long-term development objectives.

A deep institutional analysis suggests that effective territorial socio-economic development under prolonged external threats requires a transition from reactive crisis management to adaptive, digitally enabled governance. For Ukraine, this implies reconfiguring multilevel governance toward flexible coordination; redesigning fiscal institutions to address asymmetric territorial shocks; institutionalizing effective crisis-induced regulatory innovations; embedding digital governance within territorial development policy; aligning international support with endogenous institutional capacity building.

Only through such an integrated institutional approach can digital transformation and territorial resilience reinforce rather than undermine each other under prolonged external threats.

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5. Digital Transformation as a Driver of Territorial Resilience and Development. Digital transformation is frequently approached through a technologically deterministic lens, in which the diffusion of digital technologies is assumed to generate productivity gains, spatial convergence, and institutional modernization. However, contemporary territorial development theory rejects this simplification, emphasizing that digitalization is a socio-technical and institutional process whose outcomes depend on territorial context, governance structures, and historical development paths (Rodríguez-Pose & Wilkie, 2019).

From a territorial perspective, digital transformation modifies the fundamental parameters of economic coordination by altering information costs, transaction structures, and spatial dependencies. Digital networks create new forms of proximity - cognitive, organizational, and institutional - that coexist with, rather than replace, physical proximity. Consequently, digitalization reconfigures territorial hierarchies rather than eliminating them.

Under prolonged external threats, the non-neutrality of digital transformation becomes particularly salient. Territories enter the crisis with unequal levels of digital infrastructure, human capital, and institutional readiness. Digital transformation therefore acts as a multiplier of pre-existing advantages and disadvantages, making policy intervention essential to avoid cumulative divergence.

Table 3.1. Theoretical Functions of Digital Transformation in Territorial Development under Prolonged External Threats

Function of Digital Transformation	Theoretical Explanation	Relevance under Prolonged Threats
Continuity of economic activity	Digital tools reduce dependence on physical infrastructure and geographic proximity	Enables firms and workers to remain active despite destruction, displacement, and security risks
Institutional continuity	Digital governance maintains administrative functions under crisis	Ensures uninterrupted access to public services and regulatory processes
Coordination under uncertainty	Digital platforms accelerate information flows and collective action	Improves crisis response, resource allocation, and governance effectiveness
Structural reorientation	Digitalization lowers entry barriers to new sectors and business models	Facilitates transition away from disrupted traditional industries
Adaptive efficiency	Digital feedback loops support learning and experimentation	Enhances territorial capacity to adjust under persistent external pressure

Source: created by author

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This Table 3.1 systematizes what digital transformation “does” in territorial systems when threats are persistent (war, hybrid attacks, prolonged infrastructure disruption). It moves the discussion from “digitalization = efficiency” to “digitalization = continuity + adaptation.” In the Ukrainian case, the “institutional continuity” and “coordination under uncertainty” functions are especially salient because digital public services and digital coordination tools reduce dependence on physical access to administrative centers and enable continuity for displaced populations and firms. Evidence of large-scale uptake of national e-services (e.g., Diia users and usage intensity) supports the plausibility of these functions as a real institutional mechanism, not only a theoretical claim (Digital State.Ua, 2025).

Crisis theory conceptualizes prolonged external threats as conditions of systemic disruption in which standard mechanisms of coordination, accumulation, and governance are destabilized. In such environments, the primary function of digital transformation shifts from efficiency enhancement to systemic continuity and adaptability.

This shift is illustrated in Table 3.2, which contrasts traditional crisis response models with digitally enabled ones.

Table 3.2. Mechanisms Linking Digital Transformation to Territorial Resilience

Dimension	Pre-digital crisis response	Digitally enabled response
Economic organization	Location-bound, infrastructure-dependent	Remote, platform-based, networked
Governance capacity	Disrupted by displacement	Maintained via e-government
Information flows	Slow, hierarchical	Real-time, decentralized
Business adaptability	High adjustment costs	Rapid reconfiguration
Territorial resilience	Reactive	Adaptive and continuity-oriented

Source: created by author

Table 3.2 is a mechanism table: it contrasts a “pre-digital” crisis response model (location-bound, hierarchical, slow) with a digitally enabled model (network-based, real-time, flexible). Its analytic value is that it clarifies causal pathways: digital tools don’t automatically create resilience; they create the conditions for continuity (remote work, online service delivery) and faster governance feedback loops (data and coordination). For Ukraine, these mechanisms are highly relevant because prolonged threats repeatedly disrupt physical infrastructure and mobility, making digital substitution channels a core element of resilience rather than a convenience. For Ukraine, prolonged

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military aggression has repeatedly disrupted physical infrastructure and mobility. Digital substitution channels - remote work, online service provision, digital coordination - have therefore become core resilience mechanisms rather than auxiliary tools.

Digital transformation supports territorial resilience through four interrelated functions:

1. Continuity of economic activity, enabling firms to operate despite physical constraints and security risks;
2. Institutional continuity, maintaining governance capacity under conditions of displacement and infrastructural disruption;
3. Coordination under uncertainty, facilitating real-time information exchange and collective action;
4. Acceleration of structural reorientation, lowering barriers to entry in new sectors and organizational forms.

In Ukraine, these functions have been critical in sustaining territorial socio-economic systems under prolonged military aggression. Digital transformation has allowed economic and institutional processes to persist in a context where physical infrastructure and traditional supply chains have been severely disrupted.

Territorial resilience under prolonged threats requires not only the ability to withstand shocks but also the capacity to reconfigure economic and institutional structures. Digital transformation enhances what may be termed adaptive efficiency - the ability of a territorial system to experiment, learn, and adjust under uncertainty.

Theoretically, adaptive efficiency emerges from the interaction between digital technologies and institutional frameworks that permit decentralized experimentation while preserving systemic coherence (North, 1990). Digital platforms enable rapid feedback loops, data-driven learning, and flexible resource allocation, all of which are essential for adaptation in crisis conditions.

In Ukraine, territories with stronger digital ecosystems have demonstrated higher adaptive efficiency. These territories have been better able to absorb displaced firms and workers, reorient economic activity toward digital services, and integrate into global digital markets despite physical constraints.

Digital transformation produces a profound spatial reconfiguration of economic activity. While digital technologies reduce the importance of

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distance for certain activities, they do not eliminate spatial concentration. Instead, they generate a new geography characterized by selective de-territorialization.

Knowledge-intensive digital activities benefit from agglomeration effects related to skills, networks, and institutional density. As a result, digitally advanced urban regions often attract a disproportionate share of digital investment and talent. Peripheral and rural territories face the risk of marginalization unless deliberate policies address digital readiness gaps.

In Ukraine, this spatial reconfiguration is evident in the concentration of digital activity in major urban centers and relatively secure regions. At the same time, digital tools have enabled some peripheral territories to retain economic relevance by participating in remote work and digital service provision. The net territorial effect of digital transformation thus depends on the balance between agglomeration dynamics and inclusive policy design.

Digital transformation is deeply embedded in institutional structures. Its developmental impact depends on the presence of complementary institutions, including regulatory frameworks, education systems, labor market policies, and governance mechanisms.

Institutional complementarities are particularly critical under crisis conditions, where rapid digitalization may outpace institutional adaptation. Without adequate regulation, digital platforms may exacerbate labor precarity, reinforce monopolistic tendencies, and weaken local economic ecosystems.

In Ukraine, digital governance reforms have demonstrated that digital tools can strengthen institutional performance by enhancing transparency, reducing corruption risks, and standardizing administrative procedures. However, uneven institutional capacity across territories limits the uniform application of these benefits. Digital transformation therefore requires coordinated institutional reform rather than isolated technological initiatives.

Applied evidence from Ukraine highlights the centrality of digital infrastructure in sustaining territorial resilience. Broadband connectivity, cloud computing, and secure digital identity systems have enabled economic actors and public institutions to operate across territorial boundaries.

Regions with robust digital infrastructure have been better positioned to host relocated enterprises, attract digital professionals, and maintain integration into national and international value chains. Conversely, infrastructure gaps in rural and conflict-affected territories constrain economic diversification and institutional capacity.

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Public investment in digital infrastructure thus represents not merely a technological upgrade but a strategic territorial development intervention under prolonged external threats.

Digital transformation reshapes firm behavior, particularly under crisis conditions. Digital tools enable firms to reorganize production processes, access new markets, and adopt flexible employment models.

In Ukraine, the resilience of the IT sector illustrates how digitalization can offset losses in traditional industries. At the territorial level, this has allowed certain regions to maintain employment and income levels despite industrial disruption. However, the benefits of digital entrepreneurship remain unevenly distributed due to disparities in skills, capital access, and institutional support.

Digitalization also alters local economic ecosystems by increasing the importance of networks, platforms, and intangible assets. Territories lacking supportive ecosystems risk exclusion from digital growth trajectories.

Digital labor markets create new opportunities for employment and income generation independent of physical location. However, they also intensify skill-based polarization. In Ukraine, remote work has enabled skilled workers to remain economically active despite displacement. At the same time, territories with limited access to digital education and training face long-term human capital erosion.

From a theoretical standpoint, digital transformation interacts with human capital dynamics to either mitigate or reinforce territorial inequality. Inclusive digital development therefore requires coordinated investment in education, training, and social protection.

Digital public services have become a cornerstone of governance under prolonged external threats. By decoupling service provision from physical infrastructure, digital governance enhances inclusiveness and institutional continuity. In Ukraine, digital public services have ensured access to social support, business registration, and administrative procedures for displaced populations. However, governance capacity varies across territories, reflecting differences in digital skills and administrative resources.

The applied evidence suggests that digital governance must be accompanied by capacity-building at the local level to avoid reinforcing institutional disparities.

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Table 3.3. Ukraine-focused indicator set to operationalize digital transformation, disparities, and resilience

Analytical Block	Indicator (examples)	Operational definition	Territorial level	Primary Ukrainian / international sources
Digital governance uptake	Diia users; e-service usage intensity	# registered users; # requests/transactions; share of citizens using e-services	National; potentially regional if disclosed	Digital State / GovTech updates; analytical summaries
Digital skills	Registered users in Diia.Education; completion metrics	registrations / completions; digital literacy proxy	National; regional if available	Diia.Education reporting and case materials
Digital economy performance	Computer/IT services exports	Value of computer services exports (USD), monthly/quarterly	National (can be linked to regional ecosystems analytically)	Ministry of Digital Transformation summaries; NBU BoP context
Structural economic disparity	GRP and GRP per capita by oblast	Gross regional product levels and indices; per capita comparisons	Oblast	State Statistics Service of Ukraine regional accounts
Labor market stress	Unemployment / employment by region (where available); wage levels	Regional labor market outcomes as disparity and shock indicators	Oblast	State Statistics Service datasets (regional/labor modules)
Shock intensity / damage	Direct damage and needs by sector; damage by location where available	Sectoral damage (housing/energy/transport etc.); reconstruction needs	National; often oblast/sectoral breakdown in RDNA	RDNA3/RDNA4 (World Bank - GoU - EU - UN)
Displacement pressure	IDP stock and flows; concentration by region	# IDPs registered/estimated; distribution across host territories	Oblast / municipality (depending on data)	UN/UNDP reporting streams and national administrative data (where accessible)
Infrastructure resilience	Energy/transport infrastructure damage and restoration proxies	outage frequency, restored capacity, emergency road repair km (where available)	National; regional in some components	RDNA summaries and partner reporting
Digital divide	Connectivity proxies (broadband/mobile coverage); affordability proxies	coverage %, subscription rates, or speed/availability metrics (depending on dataset)	Oblast; urban/rural	Typically telecom regulator/operator reporting + national stats (availability varies) (use as an empirical module paired with Ukrstat regional data)
Institutional capacity proxy	Local fiscal capacity; revenue per capita; transfers	local budget own-revenues per capita; dependency on transfers	Community/ municipal where available; oblast aggregated	National fiscal reporting streams + research syntheses; can be paired with GRP

Source: created by author

The deep analysis indicates that digital transformation functions as a conditional driver of territorial resilience and development. Its impact depends on:

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- territorial digital readiness;
- institutional capacity and governance quality;
- human capital and skill distribution;
- policy coherence and strategic coordination.

For Ukraine, digital transformation offers a pathway to sustaining territorial development under prolonged external threats, but only if embedded within inclusive, place-based development strategies.

The integrated analysis demonstrates that digital transformation functions as a conditional and institutionally mediated driver of territorial resilience and development. In the Ukrainian context, it has enabled continuity and adaptation under prolonged external threats, while simultaneously exposing and, in some cases, reinforcing territorial inequalities. The developmental outcome of digitalization therefore depends on complementary investments in infrastructure, human capital, and institutional capacity, embedded within a coherent territorial development strategy.

6. Digital Transformation, Territorial Resilience, and Structural Disparities under Prolonged External Threats: An Empirical Assessment of Ukraine. The preceding theoretical analysis conceptualized digital transformation as a conditional and institutionally mediated driver of territorial socio-economic development under prolonged external threats. While digitalization has been widely promoted as a catalyst of economic modernization and administrative efficiency, its role in crisis-affected territorial systems remains insufficiently empirically substantiated. In contexts characterized by persistent external shocks - such as military aggression, infrastructural disruption, and large-scale population displacement - digital transformation may function simultaneously as a mechanism of resilience and as a factor reinforcing spatial inequality.

Ukraine represents a critical case for examining these dynamics. Prolonged external threats have fundamentally altered territorial development trajectories, exposing structural disparities, testing institutional capacity, and accelerating digital transformation processes. This chapter empirically investigates whether and under what conditions digital transformation contributes to territorial resilience and socio-economic stabilization in Ukraine, or whether it instead amplifies interregional divergence.

Building on the theoretical framework, the empirical analysis is guided by seven interrelated hypotheses. First, digital governance platforms reduce dependence on physical administrative infrastructure and facilitate

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institutional continuity. It is therefore hypothesized that territories exhibiting higher intensity of digital public service usage demonstrate stronger institutional resilience under prolonged external threats (H1).

Second, digitally deliverable economic activities - particularly in information and computer services - are less sensitive to physical disruption. Accordingly, greater integration into the digital economy is expected to be associated with smaller declines in territorial economic performance (H2).

Third, the effects of digital transformation are conditional. Without adequate digital infrastructure and institutional capacity, digital tools cannot be fully leveraged. Thus, the positive impact of digital transformation on territorial resilience is hypothesized to depend on complementary governance capacity (H3). Fourth, the resilience-enhancing effects of digital transformation are expected to vary across territorial types - metropolitan, relatively secure, conflict-affected, and peripheral - reflecting spatial heterogeneity in resources and constraints (H4).

Fifth, digital transformation is hypothesized to reduce territorial disparities only among territories with comparable institutional and human capital endowments (H5). In the absence of inclusive policy intervention, digitalization may instead contribute to growing interregional divergence under prolonged external threats (H6). Finally, local governance capacity is expected to moderate digital outcomes, strengthening the translation of digital transformation into territorial resilience (H7).

The empirical analysis is conducted at the oblast level, which represents the most consistent territorial unit for socio-economic, fiscal, and damage-related data in Ukraine. Territorial resilience is conceptualized as a multidimensional construct combining economic and institutional components.

To operationalize digital transformation as a systemic phenomenon, a Digital Transformation Index (DTI) is constructed as a composite indicator integrating digital governance, digital skills, and digital economic activity. Formally, the index is defined as:

$$DTI_i = \frac{1}{3}(DG_i + DS_i + DE_i) \qquad (3.1)$$

where DG_i denotes normalized digital governance usage in territory i, DS_i represents participation in digital skills initiatives, and DE_i captures a proxy for digital economic activity. All components are normalized using min - max scaling to ensure comparability across territories.

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Territorial resilience is measured through a Territorial Resilience Index (TRI) that integrates economic and institutional dimensions:

$$TRI_i = \frac{1}{2}(TER_i + IC_i) \quad (3.2)$$

where TER_i *represents territorial economic resilience, proxied by changes in gross regional product indices relative to the pre-crisis baseline, and* IC_i *reflects institutional continuity, approximated by digital public service usage intensity.*

Institutional capacity is proxied by local fiscal capacity, measured as own-source revenues per capita, reflecting the ability of local governments to sustain service provision and co-finance development initiatives. Shock intensity is captured through indicators of physical damage and reconstruction needs, as well as the concentration of internally displaced persons.

To assess the relationship between digital transformation and territorial resilience, a panel regression framework is employed. The baseline specification models territorial resilience as a function of digital transformation intensity, shock severity, and structural controls:

$$TRI_{it} = \alpha + \beta_1 DTI_{it} + \beta_2 SHOCK_{it} + \beta_3 X_{it} + \varepsilon_{it} \quad (3.3)$$

where TRI_{it} *denotes the territorial resilience index for territory* i *at time* t, DTI_{it} *captures digital transformation,* $SHOCK_{it}$ *reflects external threat intensity, and* X_{it} *is a vector of control variables.*

A positive and statistically significant β_1 supports hypotheses H1 and H2. To test the conditional nature of digital transformation effects, interaction terms are introduced to capture institutional moderation:

$$TRI_{it} = \alpha + \beta_1 DTI_{it} + \beta_2 INST_{it} + \beta_3 (DTI_{it} \times INST_{it}) + \beta_4 SHOCK_{it} + \varepsilon_{it} \quad (3.4)$$

where $INST_{it}$ *denotes institutional capacity. A positive coefficient on the interaction term* β_3 *indicates that stronger governance capacity amplifies the resilience-enhancing effects of digital transformation, consistent with hypotheses H3 and H7.*

Spatial heterogeneity is examined by interacting digital transformation with territorial typologies:

$$TRI_{it} = \alpha + \sum_k \gamma_k (DTI_{it} \times TERRTYPE_{ik}) + \beta X_{it} + \varepsilon_{it} \quad (3.5)$$

where $TERRTYPE_{ik}$ *denotes dummy variables capturing territorial categories such as metropolitan or conflict-affected regions. This specification tests hypothesis H4 regarding spatial differentiation.*

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Finally, the distributional consequences of digital transformation are assessed through a disparity model:

$$TD_t = \delta_0 + \delta_1 Var(DTI_t) + \delta_2 SHOCK_t + \delta_3 POLICY_t + u_t \quad (3.6)$$

where TD_t *measures interregional dispersion in socio-economic outcomes, and* $Var(DTI_t)$ *captures variance in digital transformation across territories. A positive* δ_1 *indicates digital polarization, supporting hypothesis H6.*

Empirical support for hypotheses H1 and H2 would indicate that digital transformation enhances territorial resilience by sustaining institutional and economic continuity under prolonged external threats. Evidence supporting the interaction effects in the conditional models would confirm that digitalization is effective only when embedded within adequate institutional capacity. Spatial differentiation results would validate the heterogeneous territorial impact of digital transformation, while disparity analysis would clarify whether digitalization functions as an equalizing or polarizing force.

The empirical framework demonstrates that digital transformation should be treated as a core element of territorial resilience policy, but only in conjunction with investments in governance capacity, infrastructure, and human capital. For Ukraine, this implies that recovery and reconstruction strategies must integrate digital transformation within place-based development policies to avoid reinforcing structural disparities.

From a research perspective, the chapter contributes to the literature on crisis-driven territorial development by offering a formalized, transferable empirical model for analyzing digital transformation under prolonged external threats.

Conclusions. The theoretical analysis provides a comprehensive framework for understanding socio-economic development of territories under conditions of prolonged external threats. By integrating insights from territorial development theory, institutional economics, crisis economics, and digital economy studies, the analysis demonstrates that prolonged external threats fundamentally transform the logic of territorial development, governance, and spatial inequality.

First, the theoretical findings confirm that prolonged external threats constitute a distinct development regime, rather than a temporary deviation from equilibrium growth paths. Unlike short-term shocks, prolonged threats generate cumulative, path-dependent effects that reshape territorial structures,

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reinforce asymmetries, and constrain convergence dynamics. Territorial development under such conditions is therefore governed less by growth maximization and more by resilience, continuity, and adaptive capacity. This reorientation necessitates a conceptual shift in territorial development theory from stabilization-oriented approaches toward adaptive and resilience-based frameworks.

Second, the analysis establishes that structural disparities are not merely outcomes but active drivers of territorial vulnerability under prolonged external threats. Pre-existing differences in economic structure, human capital, institutional capacity, and infrastructure condition the ability of territories to absorb shocks and adapt to crisis environments. Core - periphery dynamics intensify as capital, skilled labor, and innovation concentrate in institutionally stronger and safer territories, while peripheral and conflict-affected regions experience cumulative decline. Consequently, territorial inequality becomes self-reinforcing unless counterbalanced by deliberate institutional and policy interventions.

Third, the theoretical framework highlights the central role of institutions as mediators between external threats and territorial development outcomes. Institutional quality, adaptability, and multilevel governance capacity determine whether territories can transform crisis pressures into opportunities for structural adjustment or become trapped in trajectories of degradation. Under prolonged threats, institutional effectiveness depends less on regulatory stability and more on adaptive capacity, coordination, and learning. Digital governance emerges as a critical institutional innovation, capable of preserving administrative continuity and reducing transaction costs under extreme conditions, but its effectiveness remains contingent upon local administrative capacity and digital readiness.

Fourth, the analysis reconceptualizes digital transformation as an institutional and spatial phenomenon rather than a purely technological process. Digitalization alters the spatial logic of territorial development by creating new forms of proximity and connectivity, reshaping labor markets, and enabling alternative modes of economic and governance coordination. Under prolonged external threats, digital transformation assumes a dual role: it enhances territorial resilience by sustaining economic and institutional continuity, while simultaneously generating new dimensions of inequality through digital divides, skill polarization, and agglomeration effects. As a result, digital transformation functions as a conditional driver of territorial

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development whose effects depend critically on complementary institutional, infrastructural, and human capital conditions.

Fifth, the theoretical analysis demonstrates that digital transformation and structural disparities interact in non-linear and often contradictory ways. While digital technologies can reduce the importance of physical distance and enable peripheral territories to participate in economic activity, they may also reinforce core - periphery hierarchies by disproportionately benefiting territories with advanced infrastructure, skilled labor, and strong institutions. Without targeted, place-based policies, digitalization risks becoming a mechanism of digital polarization rather than territorial convergence.

Sixth, the integration of crisis economics into territorial development theory underscores that structural transformation under prolonged external threats is neither automatic nor uniformly beneficial. Crisis conditions may accelerate innovation and institutional reform in some territories, while inducing deindustrialization, human capital loss, and institutional erosion in others. Path dependency remains strong, particularly in mono-industrial and institutionally weak regions, highlighting the necessity of strategic governance and policy coordination to guide transformation trajectories.

Finally, the theoretical synthesis supports the overarching conclusion that territorial socio-economic development under prolonged external threats requires an integrated, place-based, and institutionally grounded approach, in which digital transformation is embedded within broader governance and development strategies. Digitalization alone cannot compensate for structural disparities or institutional weaknesses. Only when combined with adaptive governance, inclusive policy design, and targeted investment in infrastructure and human capital can digital transformation contribute to resilient, balanced, and sustainable territorial development.

Taken together, the theoretical conclusions provide a robust conceptual foundation for the empirical analysis and policy recommendations that follow. They reaffirm that the development of territories under prolonged external threats is shaped by the interaction of structural conditions, institutional capacity, and digital transformation, and that effective territorial policy must address all three dimensions simultaneously to avoid deepening inequality and fragmentation.

This chapter has also empirically examined the role of digital transformation in shaping territorial resilience and socio-economic development under prolonged external threats in Ukraine. The findings

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reinforce the central argument of the monograph: digital transformation is neither a panacea nor a neutral technological process. Rather, it is an institutionally mediated and spatially differentiated driver of development whose impact depends critically on governance capacity, territorial context, and policy coherence.

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Section 3.2. Challenges on ICT Market in Conditions of External Military Threats

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Abstract. *Research on information and communication technologies (ICT) markets has become a multidimensional field that combines economics, strategic management, security studies, digital governance, and resilience theory. Under external military threats, the analytical focus shifts substantially: ICT markets cannot be treated mainly as innovation-driven and globally networked systems but must be examined as vulnerable socio-technical infrastructures exposed to geopolitical conflict, cyber warfare, supply-chain disruption, and institutional instability. This context also reveals persistent fragmentation in the literature, because many approaches address technological, economic, or security dimensions separately and therefore miss their systemic interaction. This study aims to develop an integrative analytical framework for explaining ICT market dynamics under conditions of military aggression, capturing economic, technological, institutional, and security dimensions without reducing the analysis to technological determinism or security-only interpretations. ICT market resilience is conceptualized as the capacity to sustain essential connectivity, data integrity, and innovation potential under coercion and uncertainty, while remaining distinct from broader digital transformation agendas. Methodologically, the study applies qualitative integrative analysis through structured literature synthesis, comparative conceptual analysis, and mechanism mapping across economics, innovation studies, cybersecurity, institutional analysis, and security research. The findings show that conceptual plurality is analytically productive because it highlights alternative resilience pathways. A stable minimum core of resilience is identified around connectivity, data integrity, and innovation capacity, while variations reflect theoretical choices about scale and mechanisms such as decentralization, adaptive cybersecurity, international interdependence, and state–market coordination. For threatened economies, stabilization typically relies on digital redundancy, supplier diversification, cloud continuity, cross-border partnerships, and institutional reforms. Future research should apply multi-level and mixed-method designs to assess resilience under hybrid warfare and global digital fragmentation.*

Keywords: *ICT market; military threats; digital resilience; hybrid warfare; cyber security; supply-chain vulnerability; institutional volatility; technological sovereignty; crisis governance; socio-technical systems; innovation under uncertainty; geopolitical risks.*

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1. Conceptual Foundations: ICT Markets as Socio-Technical Systems Under Military Pressure. The rapid digitalization of economies has transformed information and communication technologies (ICT) into foundational infrastructures that support economic activity, state governance, societal coordination, and security systems. However, under the conditions of external military threats, the ICT market becomes uniquely exposed to multilayered risks that combine physical destruction, cyber aggression, supply chain fragility, institutional instability, and large-scale population displacement. Contemporary conflicts - such as those in Ukraine, Georgia, Israel, and the Middle East - illustrate that modern warfare targets ICT systems intentionally and systematically, exploiting their centrality to national resilience (Klimburg, 2017; Carr, 2016; Greenberg, 2019).

The central claim of this chapter is that ICT markets under conditions of external military threat must be conceptualized as socio-technical systems constituted through layered interactions between technological infrastructures, institutional orders, geopolitical alignments, and socio-cognitive processes. This conceptualization transcends reductionist interpretations that treat ICT markets either as neutral economic entities or simply as technological assemblages. Instead, the chapter argues for a more integrated analytical framework capable of explaining the heterogeneous forms of disruption, adaptation, and resilience that characterize ICT markets under coercive geopolitical conditions.

The analysis proceeds through several stages. First, it establishes theoretical foundations that frame ICT markets as complex adaptive systems where exogenous shocks reverberate across infrastructural, institutional, and behavioral dimensions. Second, it examines multiple categories of disruptions - including the destruction of physical infrastructure, cyber aggression, market volatility, human capital displacement, supply chain fragmentation, institutional instability, and shifts in demand patterns. Third, it proposes an integrated resilience framework that synthesizes economic, technological, and governance mechanisms capable of sustaining ICT sector functioning despite ongoing military threats.

Traditional market theories, which conceptualize ICT development primarily as an outcome of innovation dynamics, competition, and regulatory design, are insufficient for understanding ICT markets under military pressure. Instead, ICT ecosystems must be analyzed as socio-technical systems embedded in geopolitical conflict, hybrid warfare, and global

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technological interdependence (Baldwin & Freeman, 2023; OECD, 2022). This chapter integrates economic, technological, institutional, and security perspectives to provide a comprehensive analysis of challenges facing ICT markets during external military threats.

The ICT sector operates simultaneously as:

1. a market of goods and services;
2. a critical infrastructure system;
3. a strategic national asset;
4. a medium for communication, information dissemination, and political influence.

External military threats disrupt each of these roles in different ways. ICT markets under military conditions exhibit characteristics of high uncertainty, rapid adaptation, and asymmetric shock exposure, consistent with theories of complex adaptive systems (Boin & Lodge, 2016).

Digital infrastructure - including fiber-optic networks, cloud systems, mobile networks, and satellites - is both a target and a tool of warfare (UNESCO, 2022). Attacks on such infrastructure produce cascading failures throughout the economy. Markets cannot function without stable expectations, secure property rights, and predictable institutional environments. Military aggression undermines these conditions. ICT systems enable intelligence, surveillance, communication, and coordination - making them prime targets for cyber sabotage (NATO CCDCOE, 2021). Information is a weapon in modern hybrid warfare, affecting public trust, societal cohesion, and political processes (Fridman, 2018).

In contemporary conflicts, ICT infrastructures constitute both strategic assets and strategic targets. Physical communication networks, data centers, cloud architectures, wireless systems, and satellite constellations are increasingly integrated into military operations and thus subject to deliberate attack or indirect disruption (UNESCO, 2022). At the same time, digital platforms mediate the circulation of information, enabling actors to influence perceptions, mobilize support, or destabilize political processes. The militarization of cyberspace has further elevated the salience of ICT markets as environments in which conflict unfolds through asymmetric, deniable, and often transnational vectors (NATO CCDCOE, 2021).

ICT markets do not constitute isolated economic arenas; rather, they emerge from the interaction of technological architectures, institutional logics, human practices, regulatory regimes, and global political dynamics (Hughes,

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1987; Castells, 2010). Under conditions of external military threat, each of these dimensions becomes a potential vector of destabilization. The sector's dependence on high-reliability infrastructure, global supply chains, specialized human capital, and cross-border data flows renders it particularly susceptible to systemic fragility.

From the perspective of complex systems theory, ICT markets can be conceptualized as multi-layered adaptive systems, wherein small perturbations may produce large cascading effects due to tight coupling and high interdependence. Military threats amplify these nonlinear dynamics by introducing shocks that propagate through both physical and digital domains. The simultaneity and interdependence of cyber, kinetic, informational, and economic disruptions distinguish military-induced ICT market shocks from ordinary market fluctuations.

The embedding of ICT infrastructures into national security architectures has heightened their geopolitical significance. Data centers, telecommunication nodes, and satellite systems serve dual-use functions, supporting civilian economic operations while enabling military command, surveillance, and communication functions (Betz & Stevens, 2011). Consequently, adversarial actors may target these infrastructures to degrade state capacity, disrupt coordination, or induce broader societal paralysis.

This militarization transforms ICT networks into strategic terrain, where the boundaries between civilian and military functions become blurred. Markets operating on such terrain cannot be analyzed independently of the broader geopolitical configurations that shape threat environments (Kurbalija, 2021).

External military threats can be analytically understood as systemic shocks that operate across multiple scales (Figure 3.1). These shocks (Figure 2.2) differ fundamentally from typical economic crises because they involve intentionality, adversarial agency, and multi-domain simultaneity.

2. Disruption of Physical and Digital Infrastructure Under Military Threat. The ICT sector's infrastructural foundations - physical installations, network architectures, cloud systems, and data transmission pathways - are acutely vulnerable to the forms of violence, coercion, and infrastructural sabotage inherent in contemporary military conflicts.

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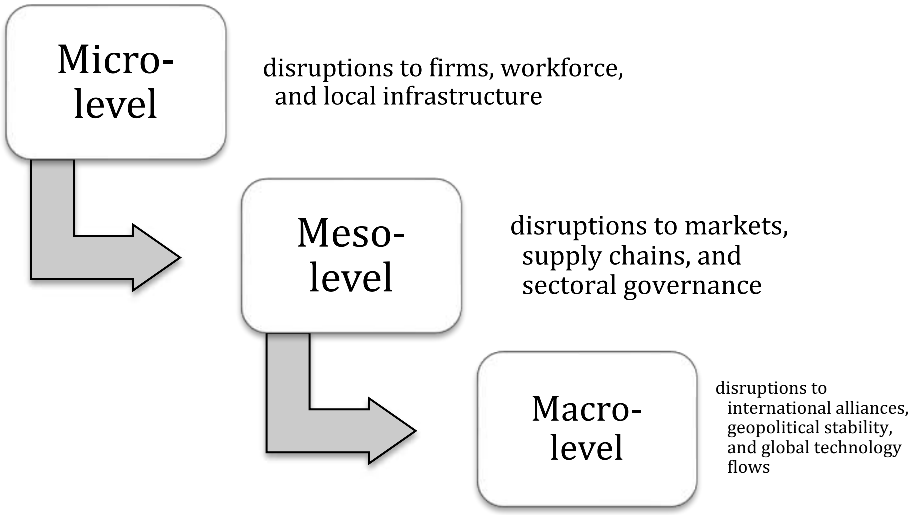

Figure 3.1. Analytical framework for external military threats systematization

Source: created by author

Unlike many other economic sectors, ICT markets depend on infrastructures characterized by high connectivity, low tolerance for interruption, and substantial spatial concentration. These characteristics render them especially susceptible to systemic destabilization.

Empirical evidence from recent conflicts demonstrates that adversarial actors increasingly target ICT infrastructures as part of coercive military strategies. The destruction of fiber-optic cables, telecommunication towers, internet exchange points, or data centers can disrupt national and regional connectivity for prolonged periods (UNESCO, 2022). Even localized damage may reverberate across network topologies due to the cascading nature of digital traffic flows.

The vulnerability of physical infrastructure must be understood within the theoretical framework of critical infrastructure interdependence. ICT systems operate as infrastructural “keystone species,” enabling other infrastructures - electricity grids, financial networks, transportation systems - to function coherently (Amin&Thrift, 2000). When ICT nodes are degraded, these dependent infrastructures experience progressive destabilization. The concentration - interdependence paradox becomes especially acute during military conflict: while centralized architectures support economies of scale and efficiency in peacetime, they significantly heighten fragility under adversarial targeting.

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The mechanisms described in Table 3.4 demonstrate that physical destruction yields more than localized interruptions; it induces cascading system failures wherein loss of redundancy impairs routing resilience, elevates latency, and reduces service reliability. From a socio-technical systems perspective, physical damage must be understood not as an isolated event but as a perturbation that destabilizes the network ecology of digital systems.

Furthermore, the destruction of ICT infrastructure often produces temporal asymmetries: it can be executed rapidly (minutes or hours), whereas recovery may require months or years due to supply shortages, labor displacement, or continued combat operations. This asymmetry constitutes a form of structural coercion, wherein the aggressor gains strategic advantage by imposing long-term technological incapacitation on the targeted society.

Table 3.4. Mechanisms of Physical ICT Infrastructure Disruption Under External Military Threats

Type of Military Action	Immediate Effect on ICT Infrastructure	Broader Systemic Outcome
Missile strikes	Destruction of fiber-optic hubs, switching nodes	Regional network blackout; loss of routing redundancy; service fragmentation
Sabotage operations	Damage to routers, servers, Internet exchange points	Network congestion, operational delays; reduced traffic capacity
Territorial occupation	Loss of access to infrastructure sites; inability to maintain equipment	Fragmented service provision; forced rerouting; long-term degradation of infrastructure integrity
Targeting of power systems	Electricity outages affecting data centres and network equipment	Data centre downtime; increased latency; failures in interdependent systems such as finance and transport

Source: created by author

This table 3.4 illustrates how different forms of military aggression affect ICT infrastructures across two levels of impact: (1) immediate operational effects, which disrupt the technical functioning of network components, and (2) systemic outcomes, which emerge from cascading failures in tightly interdependent digital systems. The table reflects the conceptual argument that physical destruction of ICT assets must be analyzed within the broader framework of critical infrastructure interdependence, where even localized assaults can produce disproportionate system-wide consequences (Amin, 2000; UNESCO, 2022).

The growing adoption of cloud technologies and distributed data

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architectures has been widely celebrated as a means of enhancing resilience by reducing dependence on localized infrastructure. While cloud-first strategies do indeed mitigate certain risks associated with territorial exposure, they introduce new forms of vulnerability associated with geopolitical jurisdiction, cross-border data sovereignty, and transnational corporate dependencies (Zhang et al., 2021; Kuner, 2020).

Under conditions of military threat, states may confront dilemmas related to the extraterritorial location of cloud resources, the potential interruption of international data flows, and the vulnerability of private cloud providers to sanctions, cyberattacks, or political pressure. Thus, while cloud-based redundancy increases operational resilience, it simultaneously embeds ICT markets more deeply in global geopolitical networks, making them susceptible to disruptions not only from local conflict but from international realignments.

3. Cyber Threats, Hybrid Warfare, and the Strategic Destabilization of ICT Markets. External military threats increasingly unfold within an expanded battlespace that encompasses both physical and digital domains. Whereas earlier forms of conflict primarily relied on kinetic force, contemporary military strategies integrate cyber operations, information manipulation, digital espionage, and psychological operations into coordinated hybrid campaigns (Fridman, 2018; Greenberg, 2019). ICT markets are uniquely exposed to such dynamics due to their structural dependence on data integrity, trust relationships, and uninterrupted connectivity.

Cyber operations can be conceptualized as adversarial interventions into the epistemic and operational foundations of ICT ecosystems. These interventions target the confidentiality, integrity, and availability of data and infrastructure - the so-called CIA triad - and thereby destabilize both technological and market functioning (ENISA, 2023). Importantly, cyber threats do not manifest solely as isolated technical events; rather, they constitute socio-technical disturbances that propagate across institutional, organizational, and behavioural domains.

Contemporary military threats are associated with a measurable intensification of cyberattacks directed against ICT firms, cloud providers, telecommunication operators, and state-critical digital services. These attacks evolve along three principal dimensions:

1) scale - the number of simultaneous attack vectors;

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2) complexity - the sophistication of malware and threat actor capabilities;

3) temporal orchestration - the coordination of cyberattacks with kinetic or informational operations (NATO CCDCOE, 2021).

It is important to emphasize that cyber threats in military contexts perform both instrumental and symbolic functions. Instrumentally, they degrade infrastructure performance, interrupt communication flows, and exfiltrate sensitive information. Symbolically, they erode public confidence, amplify uncertainty, and weaken the perceived legitimacy of state and market institutions. This dual function underscores the hybrid character of contemporary cyber conflict.

Table 3.5. Categories of Cyber Threats and Their Systemic Effects on ICT Markets Under Military Conditions

Cyber Threat Type	Mechanism of Impact on ICT Systems	Systemic Market Consequence
Wiper malware (e.g., NotPetya)	Destruction of system files; corruption of core data structures	Prolonged service outages; loss of consumer and enterprise trust; reputational damage
Distributed denial-of-service (DDoS) attacks	Overloading servers and networks, saturating bandwidth	Decreased stability of digital services; interruptions to payment systems; operational losses
Advanced persistent threats (APTs)	Long-term infiltration; credential theft; espionage	Intellectual property loss; competitive disadvantages; heightened insurance and compliance costs
Phishing and credential-harvesting operations	Exploitation of human vulnerabilities; unauthorized access	Expanded attack surface; financial loss; breach of sensitive client information
Coordinated disinformation campaigns	Manipulation of information flows; erosion of trust	Market volatility; reputational fragmentation; reduced adoption of digital services

Source: created by author

The systemic consequences enumerated in Table 3.5 highlight the complex interplay between technical vulnerabilities and market dynamics. Unlike natural disasters or accidental outages, cyberattacks perpetrated in military contexts are epistemically opaque and temporally indeterminate, creating persistent uncertainty in ICT markets. This uncertainty functions as a structural impediment to investment, innovation, and long-term strategic planning (WEF, 2023).

Moreover, the hybrid integration of disinformation campaigns with cyber

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operations transforms ICT infrastructures into arenas of cognitive conflict, wherein adversaries seek to destabilize public trust, institutional legitimacy, and informational reliability (Pomerantsev, 2019). As a result, cyber threats under military conditions must be understood not merely as technological events but as multi-domain disturbances that reshape economic behavior and decision-making.

4. Market Volatility, Structural Reallocation, and the Political Economy of ICT Under Military Threat. External military threats produce profound disturbances across ICT market dynamics. These disturbances arise from the confluence of heightened risk perception, capital flight, interrupted supply chains, labour displacement, and the reorientation of state priorities toward defence. ICT markets, which normally thrive in environments characterized by temporal continuity and regulatory stability, experience structural reallocation pressures and sectoral asymmetries during conflict (Baldwin & Freeman, 2023).

Military threats alter the risk calculus of investors by increasing uncertainty and reducing the predictability of future revenue streams. Private capital becomes more risk-averse, leading to declines in venture financing, the postponement of research and development projects, and the reevaluation of market entry decisions (WEF, 2023). Such contractions have especially profound effects on economies with emerging ICT sectors, where foreign direct investment constitutes a key driver of technological upgrading.

At the same time, state intervention often increases as governments attempt to stabilize essential digital services, regulate cyber vulnerabilities, and strengthen national security - oriented ICT capacities. These interventions reshape the political economy of ICT markets by increasing the role of sovereign funding, public - private partnerships, and defence-oriented procurement schemes.

Whereas general consumer-oriented ICT segments may contract during military conflict, defence-oriented ICT niches often expand rapidly, driven by heightened demand for secure communications, surveillance technologies, cybersecurity systems, and AI-enabled battlefield analytics (Friedman et al., 2022).

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Table 3.6. Differentiated Sectoral Dynamics in ICT Markets During External Military Threats

ICT Market Segment	Observed Trend Under Conflict Conditions	Underlying Mechanism
Consumer electronics	Decline	Reduced purchasing power; disrupted imports
Enterprise software	Slowdown	Deferred investment; operational uncertainty
Cybersecurity	Accelerated growth	Intensified cyber threats; heightened regulatory mandates
Cloud computing and hosting	Moderate growth	Need for redundancy and remote accessibility
Defense-tech (AI, drones, ISR systems)	Rapid expansion	Military procurement; battlefield digitization

Source: created by author

Table 3.6 reveals that external military threats generate a dual transformation in ICT markets. On the one hand, market contraction occurs in consumer and enterprise domains due to diminished purchasing power, heightened uncertainty, and disrupted economic activity. On the other hand, military-induced demand structures catalyse accelerated growth in specialized sub-sectors. This bifurcation illustrates how conflict reconfigures the innovation frontier, prioritizing technologies that support surveillance, resilience, and strategic advantage.

This dynamic also reflects what scholars refer to as security-induced technological acceleration, whereby wartime conditions compress innovation cycles and shift resource allocation toward technologies with immediate strategic value (von der Gracht et al., 2021). The long-term consequences of such reallocations remain ambiguous: while defence-oriented innovation can spill over into civilian markets, it may also entrench militarized technological paradigms and crowd out investment in broader digital transformation.

5. Human Capital Shocks, Labor Fragmentation, and Cognitive Strain in ICT Markets. Human capital constitutes the primary productive resource in ICT markets. Highly skilled software engineers, network architects, cybersecurity specialists, and data scientists embody tacit knowledge, creativity, and technical competencies that cannot be easily replaced. External military threats disrupt the reproduction of human capital in multiple ways: through forced migration, mobilization, life-cycle interruptions, and disruptions to educational institutions (Akcigit et al., 2021).

The displacement of ICT specialists produces structural talent

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asymmetries, where firms experience sudden shortages of critical expertise. These shortages diminish firms' innovation capacity, reduce productivity, and undermine the competitive position of the domestic ICT sector. Human capital displacement may also lead to the externalization of innovation as skilled workers relocate to foreign firms, contributing to long-term technological divergence.

Beyond physical displacement, military threats impose substantial psychological burdens on ICT professionals. Cognitive strain, emotional stress, and trauma impair decision-making, problem-solving capabilities, and collaborative functioning (World Bank, 2022). For organizations, this manifests as reduced productivity, higher turnover, and weakened team cohesion.

The shift to remote work - while beneficial for maintaining operational continuity - cannot fully mitigate the loss of in-person collaboration, mentoring networks, and embedded tacit knowledge.

Table 3.7. Human Capital Disruptions in ICT Markets During Military Conflict

Type of Human Capital Shock	Mechanism	Market-Level Outcome
Forced migration and displacement	Loss of skilled ICT labour; diaspora formation	Reduced innovation capacity; weakened local firms
Military mobilization of ICT specialists	Removal of key personnel from productive roles	Project delays; reduced service continuity
Psychological distress and trauma	Impaired cognitive performance; burnout	Lower productivity; reduced organizational coherence
Disruption of educational institutions	Interrupted training pipelines	Long-term talent shortages; diminished competitiveness
Fragmentation of professional networks	Loss of collaboration and tacit knowledge flows	Slowdown in technological diffusion and innovation

Source: created by author

Human capital shocks in ICT markets must be understood within the broader theoretical framework of knowledge-based economies, where innovation depends on the cumulative interaction of skills, experience, and social networks (Foray, 2004). The displacement or demobilization of skilled workers therefore produces systemic effects that reverberate across innovation ecosystems, reducing the sector's absorptive capacity and weakening its integration into global technological circuits.

Human capital erosion is particularly severe because it generates path-

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dependent consequences: once a country loses its critical mass of ICT talent, rebuilding such capacity requires prolonged investment and institutional stability - conditions often absent under continued military threat.

6. Supply Chain Disruptions, Technological Dependence, and the Geopolitics of ICT Production. The ICT sector is deeply embedded in globally distributed supply chains that depend on the uninterrupted flow of semiconductors, microelectronics, specialized hardware, rare-earth elements, and proprietary software (OECD, 2022). External military threats disrupt these flows through direct attacks, transport corridor blockages, trade sanctions, and geopolitical reconfigurations.

Semiconductors serve as foundational components within all ICT devices and infrastructures. Their production is concentrated within a small number of countries, making global supply chains vulnerable to geopolitical tensions (Baldwin & Freeman, 2023). During military conflicts, access to semiconductors becomes constrained, leading to production delays, cost inflation, and reduced technological competitiveness.

Military conflicts disrupt logistics networks by making transport routes unsafe, increasing insurance premiums, and causing border closures. These disruptions impose substantial transaction costs on ICT firms, forcing them to adjust procurement strategies or reduce production.

Table 3.8. Supply Chain Vulnerabilities in ICT Markets Under Military Threat

Dependency Type	Triggering Event	Impact on ICT Market Functioning
Semiconductor imports	Border closures; export controls	Production bottlenecks; inability to manufacture ICT hardware
Cloud and data services	Geopolitical sanctions; jurisdictional conflicts	Service interruptions; data accessibility constraints
Foreign software licenses	Restrictive export regimes	Loss of critical functionality; operational paralysis
International logistics	Destruction of transport infrastructure; blocked corridors	Delayed deliveries; cost inflation; supply scarcity
Telecommunications equipment	Supplier withdrawal; plant shutdowns	Network maintenance failures; reduced capacity for expansion

Source: created by author

Supply chain vulnerabilities must be interpreted within the conceptual lens of geopolitical embeddedness, wherein ICT markets depend on cross-border technological exchanges shaped by power asymmetries and strategic rivalries (Farrell & Newman, 2019). External military threats expose the risks

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ISBN 978-9916-9320-3-2 (pdf)

inherent in such dependencies by revealing the extent to which domestic ICT capacity is conditioned by exogenous actors.

This situation generates a strategic imperative for technological sovereignty, prompting states to diversify suppliers, invest in domestic production capabilities, or develop regional partnerships. However, such efforts require significant time, capital, and expertise, rendering full independence impractical for most countries.

8. Institutional Instability, Regulatory Fragmentation, and Governance Challenges Under Military Threat. Institutional environments constitute the meta-structural scaffolding upon which ICT markets rely for predictability, coordination, and legitimacy. Unlike purely technical disruptions, institutional disruptions alter the rules of interaction, reshape incentive architectures, and erode the normative and cognitive expectations that underpin functioning markets (North, 1990). Under external military threat, these disruptions intensify due to crisis-induced governance realignment, accelerated bureaucratic decision-making, and reallocation of state capacity toward security-oriented imperatives.

Military threats impose a dual strain on the state:

1. Compression - institutions must rapidly contract their priorities, concentrating attention on immediate security, cyber defence, civil protection, and diplomatic crisis management.
2. Overextension - institutions must simultaneously expand operational mandates to include emergency regulation of ICT infrastructures, expanded surveillance, and cybersecurity coordination.

This creates an endogenous contradiction where the state becomes both more directive and less capable, a dynamic similar to what Boin and Lodge (2016) describe as *institutional unbalancing*. ICT markets, which require stable governance parameters, thus face an environment where regulatory intentions escalate but administrative capacity diminishes.

A major institutional consequence of military threat is the collapse of long-term regulatory planning. ICT sectors depend on multi-year strategies concerning spectrum allocation, digital transformation, broadband expansion, and innovation policy. Under crisis conditions, these time horizons are disrupted by:

- Accelerated timelines for cybersecurity mandates;
- Suspension of long-term digital infrastructure plans;
- Rapid amendments of data governance laws;

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– Short-termism in policy prioritization.

These shifts produce what scholars identify as a temporal governance shock, in which the sequencing and stability of policy measures become unpredictable (Howlett, 2019). Such instability reduces investor confidence, increases compliance costs, and weakens public - private coordination.

External military threats expose fissures across regulatory institutions responsible for ICT markets. Security agencies prioritize secrecy, control, and rapid threat mitigation, while digital innovation agencies focus on openness, interoperability, and experimentation. Telecom regulators prioritize continuity and competition. These competing logics generate institutional incoherence, where regulatory signals conflict or overlap.

The fragmentation is further aggravated when ICT infrastructures become entwined with intelligence operations, restricting transparency and creating operational silos that hinder interagency coordination.

Table 3.9. Institutional and Regulatory Challenges Affecting ICT Markets Under External Military Threats

Institutional Challenge	Mechanism	Analytical Implication	Market Outcome
Emergency cybersecurity mandates	Rapid imposition of new obligations	Institutional time compression; regulatory overload	Compliance uncertainty; cost escalation
Inter-agency mandate fragmentation	Overlapping authorities (defense, telecom, digital ministries)	Conflicting regulatory logics; policy incoherence	Investor hesitation; slow implementation
Jurisdictional conflict over cloud governance	Divergent national vs. foreign provider rules	De-sovereignization risk; regulatory misalignment	Infrastructure dependence; legal exposure
Crisis-driven administrative overload	Overextension of state responsibilities	Declining administrative quality; bottlenecks	Slowed approvals; stalled innovation
Security-driven policy reorientation	Dominance of coercive institutional logics	Reduction of market liberalization space	Constrained ICT market competition

Source: created by author

Institutional instability under military threat reveals the extent to which ICT markets are institutionally co-produced systems, where technological functioning depends on regulatory coherence and governance legitimacy. Theories of institutional layering (Mahoney & Thelen, 2010) help explain how conflicting layers of emergency regulation interact with pre-existing digital governance frameworks, creating hybrid and sometimes contradictory

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structures. ICT markets thereby confront institutional pathologies - such as incoherence, volatility, and misalignment - that impede adaptation and resilience.

Furthermore, governance fragmentation produces what Farrell and Newman (2019) describe as weaponized interdependence - a condition where states' dependence on transnational digital infrastructures enables external actors to exert coercive pressure. Under military threat, regulatory institutions must therefore navigate an increasingly precarious realm of strategic interdependence, balancing domestic sovereignty concerns with reliance on foreign cloud and hardware providers.

Whereas infrastructural and institutional disruptions are structural, demand-side transformations reflect the behavioral and cognitive adaptation of market actors. ICT markets, perhaps more than any other sector, depend on expectation stability; trust in digital systems; psychological readiness to adopt innovation; risk perception patterns.

Under military threat, these conditions are profoundly altered. Military conflict triggers what Kahneman and Tversky (1979) describe as loss-aversion dominance, where consumers prioritize immediate survival needs over long-term investments, including ICT purchasing. Households delay or cancel purchases of new devices, subscription services, home electronics, digital entertainment platforms. Yet paradoxically, demand for secure communication, information access, and identity-protecting technologies increases. This bifurcation represents a threat-induced consumption asymmetry.

Firms exhibit heightened risk aversion, reducing ICT procurement related to digital transformation, automation, cloud migration and enterprise resource planning (ERP) upgrades.

These decisions reflect a reversion to operational minimalism, where firms maintain only essential digital services. This behaviour has long-term consequences for national competitiveness, as delayed ICT modernization dampens productivity, reduces innovation capability, and erodes integration into global digital value chains (Baldwin & Freeman, 2023).

Demand-side patterns are also shaped by collective perceptions of digital vulnerability. When populations believe digital infrastructures may be compromised - via cyberattacks, surveillance, or disinformation - they adjust behaviours accordingly. These behaviours include reduced use of digital payment systems, selective information consumption, increased reliance on

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encrypted communication, scepticism toward government digital services.

The result is a trust-mediated market contraction, where the erosion of confidence in digital platforms directly reduces market dynamism.

Table 3.10. Demand-Side Shifts in ICT Markets During External Military Threat Conditions

Market Actor	Behavioural Shift	Underlying Psychological/Economic Mechanism	Macro-Level Outcome
Households	Decrease in discretionary ICT spending	Loss aversion; income uncertainty; security prioritization	Contraction of consumer ICT market
Enterprises	Deferral of ICT modernization	Risk aversion; liquidity constraints; operational conservatism	Slowed national digital transformation
Governments	Increase in defence-tech adoption	Strategic necessity; battlefield digitization	Expansion of military ICT segments
Society	Increased use of secure communication and information vetting	Perceived digital vulnerability; social coordination needs	Growth of cybersecurity demand
International buyers	Reduced outsourcing to conflict-affected economies	Perceived operational risk; reputational concerns	Decline in ICT exports; reduced foreign revenue

Source: created by author

Demand-side dynamics under military threat illustrate the behavioural elasticity of ICT markets. Unlike sectors with material consumption, ICT markets reflect information-based decision processes where threat perception, social learning, and cognitive heuristics - rather than pure purchasing power - shape demand trajectories.

The demand contraction in innovation-intensive segments also reflects a precautionary equilibrium, where actors refrain from engaging in high-risk technological investments. This equilibrium is challenging to reverse even after conflict subsides, leading to path-dependent stagnation.

10. Multi-Layered Framework for ICT Market Resilience. Resilience in ICT markets should be understood across three analytically distinct but interdependent dimensions:

1. Functional resilience - the ability to maintain connectivity, data integrity, and operational continuity.

2. Structural resilience - the architectural features that prevent cascading failures.

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3. Institutional resilience - the governance configurations that sustain coordinated adaptation.

The interaction among these layers produces emergent resilience, not attributable to any single component.

A robust ICT resilience strategy must incorporate strategic depth, ensuring that redundancy and adaptability are embedded across geographically distributed assets; jurisdictionally diversified cloud architectures; multi-provider supply chains; sovereign cyber capabilities; resilient human capital pipelines. This depth reduces the probability that a single point of failure - physical or institutional - undermines market stability.

Table 3.11. Integrated Multi-Dimensional ICT Resilience Framework

Resilience Layer	Mechanisms/Components	Analytical Function	Resilience Outcome
Infrastructural	Distributed cloud; mesh networks; hardened data centers	Spatial redistribution of risk; failure containment	Enhanced continuity under attack
Cybersecurity	Threat intelligence; zero-trust architecture; SOC integration	Reduction of attack surface; accelerated detection	Mitigation of cyber-induced market instability
Market Design	Supplier diversification; sovereign ICT investment	Reduction of geopolitical dependency; supply resilience	Stabilized innovation trajectories
Human Capital	Remote talent mobility; digital skills resilience programs	Continuity of tacit knowledge; cognitive readiness	Sustained innovation capacity
Institutional Governance	Adaptive regulation; cross-agency harmonization	Governance coherence; expectation stabilization	Higher regulatory predictability
International Cooperation	Bilateral CERT networks; cloud sovereignty partnerships	Shared defense capacities; mutual redundancy	Lower systemic fragility

Source: created by author

This framework aligns with complex adaptive system theory, where resilience emerges from distributed capacities, redundancy, adaptability, and multi-level coordination (Holland, 2012). ICT resilience is not merely a technical matter but a systemic phenomenon involving engineered robustness, institutional adaptability, behavioural elasticity and geopolitical redundancy.

The chapter demonstrates that ICT resilience under military threat demands the alignment of technology, institutions, markets, and geopolitics, supported by sustained state capacity and international collaboration.

Conclusions. ICT markets under external military threat confront threats that are simultaneously material, digital, institutional, and behavioural,

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revealing the full extent of their embeddedness in modern socio-technical and geopolitical systems. The analysis demonstrates that ICT vulnerabilities are multidimensional, spanning infrastructure, regulation, supply chains, human capital, and cognition. Military threats function as systemic disruptions, destabilizing expectation frameworks and market equilibria. Governance fragmentation and institutional volatility amplify market fragility. Demand-side behavioural adaptations contribute to prolonged ICT stagnation. Resilience requires multi-layered, cross-domain strategies, not isolated technological fixes.

A central contribution of this chapter is the articulation of a holistic, socio-technical resilience framework capable of guiding policymakers and market actors in designing ICT systems that can withstand military and hybrid threats. Ultimately, ensuring ICT resilience is inseparable from safeguarding national economic sovereignty, sustaining innovation ecosystems, and maintaining the continuity of societal coordination in an era of evolving geopolitical instability.

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Section 3.3. Artificial Intelligence as a Driver of Business Competitiveness in the Context of Digital Transformation

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Abstract. *Artificial intelligence (AI) has become a defining driver of organizational transformation and competitive restructuring in the global digital economy. As firms navigate accelerating technological change, heightened market turbulence, and increasing institutional complexity, AI emerges not merely as a technological instrument but as a systemic capability that reshapes strategic priorities, operational architectures, and industry-level competitive dynamics. In this context, understanding how AI generates and amplifies competitive advantage requires a multidimensional analytical approach that integrates technological, organizational, and institutional perspectives. The aim of this section is to develop a comprehensive analytical framework for explaining how AI functions as a driver of business competitiveness within conditions of digital transformation. The methodological framework of the chapter is grounded in a combination of theoretical synthesis, mechanism-based analysis, and comparative sectoral assessment. Conceptual models, maturity frameworks, and structured tables are employed to systematize AI-driven transformation processes and to clarify the causal pathways linking AI capabilities to competitive outcomes. The empirical grounding derives from cross-sectoral evidence documented in contemporary digital transformation research, complemented by case-based insights from manufacturing, finance, logistics, retail, and healthcare. The results of the analysis demonstrate that AI enhances competitiveness through a layered architecture of operational, cognitive, and strategic mechanisms, while simultaneously reshaping industry structures through platformization, ecosystem formation, and data-driven coordination. At the organizational level, AI maturity, governance quality, and dynamic capability development emerge as critical determinants of competitive differentiation. At the macro level, national competitiveness increasingly depends on institutional readiness, digital infrastructure, human capital, and regulatory coherence. Overall, the findings highlight that sustainable competitive advantage in the AI era requires systemic alignment across technology, organizational capabilities, and institutional frameworks, as well as continuous adaptation to evolving digital ecosystems.*

Keywords: *artificial intelligence; digital transformation; business competitiveness; dynamic capabilities; platform economics; institutional theory; socio-technical systems; AI governance; industry restructuring; innovation ecosystems.*

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1. AI as a General-Purpose Technology and Competitive Resource. The accelerated integration of artificial intelligence (AI) into business processes has become one of the defining forces reshaping competitive dynamics in the global economy. As digital transformation permeates all sectors – from manufacturing and logistics to finance, healthcare, and creative industries – AI emerges not merely as a set of tools but as a general-purpose technology (GPT) capable of generating pervasive spillovers, inducing structural change, and reconfiguring entire competitive landscapes (Brynjolfsson & McAfee, 2017; Agrawal et al., 2018).

While digital transformation traditionally emphasized automation, datafication, and process optimization, the diffusion of AI shifts the strategic focus toward cognitive augmentation, predictive analytics, autonomous decision-making, and adaptive competitive capabilities. Thus, AI becomes a central driver of business competitiveness by enhancing not only operational efficiency but also innovation capacity, organizational learning, and dynamic strategic repositioning.

In conditions of global digitalization, where markets become increasingly integrated, transparent, and data-driven, firms unable to adopt AI face widening productivity gaps, reduced strategic agility, and declining market positions. This chapter argues that AI functions as a multi-dimensional competitiveness catalyst, influencing firms through:

1. Technological mechanisms (automation, optimization, prediction).
2. Organizational mechanisms (learning, coordination, decision-making).
3. Market mechanisms (differentiation, scalability, speed of response).
4. Institutional mechanisms (compliance, transparency, innovation ecosystems).

The study develops an analytically detailed and mechanistic explanation of how AI generates competitive advantages, including:

- capability-based frameworks;
- value-creation architectures;
- AI-driven business model transformation;
- mechanisms of competitive asymmetry;
- typologies of AI-induced performance differentials;
- sectoral pathways of AI impact;
- resilience and adaptation mechanisms.

AI exhibits the core characteristics of GPTs identified in economic theory:

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1. Pervasiveness - applicable across multiple industries.
2. Continuous improvement - learning dynamics generate compounding performance.
3. Complementarity - synergizes with human capabilities, data, digital infrastructure, and organizational routines.
4. Innovation inducement - stimulates new applications, products, and business models.

Because GPTs restructure factor productivity, AI fundamentally reshapes the competitive landscape by shifting production frontiers and creating new competitive equilibria (Bresnahan & Trajtenberg, 1995).

Within strategic management, AI functions as a VRIN resource – valuable, rare, inimitable, and non-substitutable – when embedded in firm-specific data assets, algorithmic models, and organizational knowledge routines (Barney, 1991).

AI as a VRIN Resource:

- Valuable: improves efficiency, speed, accuracy;
- Rare: proprietary datasets and domain-tuned models;
- Inimitable: path-dependent learning and model training;
- Non-substitutable: no comparable technologies produce similar cognitive augmentation.

AI thereby becomes a central element of sustained competitive advantage, especially when combined with unique data ecosystems.

Digital transformation requires firms to develop dynamic capabilities – the ability to sense opportunities, seize them, and reconfigure resources (Teece, 2007). AI enhances all three:

- Sensing: predictive analytics identify emerging trends;
- Seizing: AI optimizes resource allocation;
- Reconfiguring: automation and learning models support organizational restructuring.

Firms that successfully integrate AI into dynamic-capability architectures demonstrate accelerated innovation cycles and superior market responsiveness.

Rather than treating AI as an abstract enabler, this chapter adopts a mechanism-based explanatory approach, identifying causal pathways through which AI generates competitive outcomes:

- Efficiency mechanisms (cost reduction, cycle time compression);
- Intelligence mechanisms (forecasting, anomaly detection);

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- Autonomy mechanisms (self-optimizing systems, autonomous decision loops);
- Scalability mechanisms (AI-driven growth with low marginal cost);
- Differentiation mechanisms (personalization, service uniqueness);
- Strategic mechanisms (market creation, disruption, competitive asymmetry).

These mechanisms create AI-induced competitiveness gradients across firms, sectors, and regions.

2. Strategic Dynamics of AI Adoption and Competitive Asymmetry. AI adoption does not occur uniformly across firms or industries. Instead, AI produces competitive asymmetries, whereby early adopters and technologically sophisticated firms accumulate disproportionate advantages, while late adopters face growing barriers to catch-up.

Firms rarely adopt artificial intelligence in a uniform or instantaneous manner. Instead, empirical evidence and theoretical models of technological diffusion indicate that organizations typically progress through a multistage AI maturity trajectory, each stage reflecting distinct structural, technological, and strategic characteristics. These stages can be conceptualized as follows on Figure 3.2 and in Table 3.12.

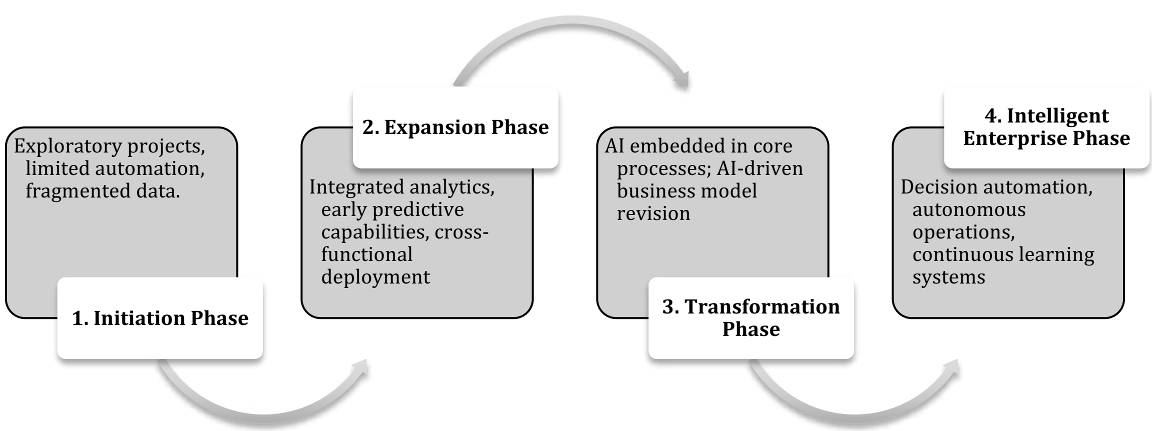

Figure 3.2. The AI Adoption Curve and Competitiveness Phases

*Source: created by author based on (*Agrawal et al., 2019; Brynjolfsson & Mcafee, 2017)

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Table 3.12. Phases of AI Adoption and Their Competitive Outcomes

AI Adoption Phase	Technological Characteristics	Competitive Outcomes
Initiation	Isolated tools, pilot projects	Marginal efficiency gains; limited impact
Expansion	Integrated analytics, enterprise-wide data	Improved operational KPIs; emerging differentiation
Transformation	Predictive and prescriptive AI, data-driven culture	Structural cost advantage; accelerated innovation
Intelligent Enterprise	Autonomous systems, real-time learning	Market leadership; disruptive potential; network effects

Source: created by author

The initiation phase is early phase characterized by exploratory experimentation, limited pilot projects, and ad hoc applications of automation. Data assets remain highly fragmented, governance structures are underdeveloped, and AI capabilities function as isolated tools rather than integrated components of organizational processes. Competitive effects at this stage are minimal, often confined to incremental efficiency gains.

Organizations begin to establish enterprise-wide data architectures that enable integrated analytics and the first generation of predictive modeling capabilities. AI is deployed in multiple functional areas – marketing, operations, risk management – though typically without full strategic alignment. Competitive outcomes become more visible as firms achieve improved process performance and emerging differentiation relative to slower adopters.

At the transformation phase AI becomes embedded in core operational and strategic routines, enabling prescriptive decision-making, workflow redesign, and the restructuring of resource allocation mechanisms. Firms frequently initiate AI-driven business model innovation, shifting from traditional value propositions toward data-centric and service-oriented configurations. Competitive effects intensify, producing structural cost advantages and accelerated innovation cycles.

Intelligent enterprise phase represents the culmination of AI maturity, wherein organizations operate as continuously learning socio-technical systems. Decision-making processes become increasingly automated, and operational activities are coordinated through autonomous or semi-autonomous AI agents. The firm achieves high levels of adaptability, real-time responsiveness, and strategic foresight. Competitive outcomes include defensible market leadership, ecosystem dominance, and the capacity to

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influence industry standards.

Collectively, these phases demonstrate that AI adoption is not merely a technical process but a progressive transformation of organizational cognition, structure, and strategy, with each phase generating qualitatively distinct competitive implications.

Artificial intelligence (AI) operates as a structural amplifier of pre-existing inter-firm heterogeneities, magnifying differences in data accessibility, computational infrastructure, managerial literacy, integration capability, and innovation culture. As firms attempt to harness AI within their organizational processes, these disparities translate into uneven absorptive capacity and produce what may be described as a productivity bifurcation: technologically advanced firms experience accelerated, often exponential performance gains, while firms with limited AI readiness exhibit stagnation or decline. This divergence is sustained through several mutually reinforcing mechanisms, including compounding data advantages, positive feedback loops in learning systems, capital concentration in AI infrastructure, talent acquisition asymmetries, and economies of scale in automation. At the industry level, AI restructures competitive dynamics through platformization, ecosystem formation, servitization, and disintermediation, thereby altering value creation logics and shifting the locus of competitive advantage. Sectors such as finance, retail, logistics, manufacturing, professional services, and healthcare exhibit differentiated AI impact trajectories, shaped by variation in data intensity, regulatory environments, and technological maturity. Importantly, AI simultaneously reinforces and disrupts existing competitive structures: it strengthens incumbents endowed with extensive data ecosystems, scale advantages, and robust AI governance, yet it also enables entrepreneurial entrants to design AI-native business models, create novel markets through intelligent products, and exploit strategic vulnerabilities in legacy organizations. This duality underscores AI's function as a destabilizer of competitive equilibria, generating both consolidation and fragmentation pressures within contemporary digital markets.

3. Understanding AI-Driven Business Competitiveness. Artificial intelligence does not merely function as a technological supplement to business processes; rather, it operates as a foundational paradigmatic shift that transforms the logic of competition, value creation, and organizational capability development. To situate AI strategically within the context of digital transformation, this section synthesizes a set of advanced theoretical

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frameworks that together illuminate the causal mechanisms through which AI generates competitive advantage.

Within the evolutionary economics tradition, firms are conceptualized as heterogeneous entities whose performance is shaped by the interplay of variation, selection, and retention mechanisms (Nelson & Winter, 1982). Artificial intelligence fundamentally accelerates and intensifies these evolutionary dynamics. On the variation dimension, AI expands the space of feasible organizational experimentation by enabling high-velocity simulation, generative modeling, combinatorial search, and automated hypothesis testing. In the context of selection, machine learning algorithms systematically evaluate extensive design spaces, identifying functionally superior solutions with levels of precision and scale that exceed human analytical capacity. Regarding retention, AI systems codify effective routines into digital workflows, algorithmic parameters, and institutionalized data pipelines, thereby embedding learned competencies into the firm's operational architecture. Consequently, AI does not merely automate existing processes; it amplifies the evolutionary trajectory of the firm by accelerating innovation generation, compressing performance feedback loops, and deepening organizational learning mechanisms. In this sense, AI constitutes a dynamic selection environment in which firms incapable of adapting their routines, capabilities, and strategic orientations to AI-enabled conditions become progressively disadvantaged and ultimately outcompeted by more evolutionarily responsive organizations.

Complexity theory conceptualizes firms as complex adaptive systems situated within dynamic and interdependent environments characterized by turbulence, uncertainty, nonlinear feedback loops, and continuous structural change (Holland, 2012). Within this framework, artificial intelligence operates not as a mechanism for reducing complexity but as a computational augmentation that enhances an organization's capacity to perceive, interpret, and respond to such complexity. AI extends real-time sensing capabilities by extracting signal from noise across vast, multidimensional data environments; it reduces epistemic uncertainty through the modeling of nonlinear relationships that are inaccessible to traditional analytical methods; and it facilitates rapid organizational adaptation through automated reconfiguration of processes, resource allocations, and operational workflows. Moreover, AI stabilizes performance under volatile conditions by generating predictive insights, enabling proactive interventions, and increasing systemic robustness.

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As firms confront environments marked by turbulence, interdependency, and dynamic competitive pressures, AI materially improves their adaptive fitness, not by simplifying the underlying complexity but by equipping them with the computational and analytical capacities required to navigate it effectively.

From the perspective of cognitive systems theory, artificial intelligence functions as a profound extension of organizational cognition – the ensemble of processes through which firms perceive environmental signals, interpret information, and translate insights into coordinated action. Traditional forms of organizational cognition are constrained by bounded rationality, limited attentional resources, slow and often imprecise pattern recognition, and fundamental human limitations in processing scale, speed, and complexity. AI-augmented cognition, by contrast, is characterized by virtually unbounded data ingestion, the capacity for high-dimensional pattern recognition, near-zero latency in information processing, and an ability to identify anomalies and latent structures that lie beyond human perceptual thresholds. In this expanded cognitive architecture, AI enhances the firm's perceptual capacity by broadening its sensing range across diverse data environments; it amplifies interpretive capacity by extracting meaningful structure from complex and nonlinear information; it strengthens decision capacity through computational reasoning and probabilistic inference; and it augments action capacity by enabling the automated execution of context-appropriate responses. Firms that develop advanced AI-enabled cognitive infrastructures thus acquire superior organizational intelligence, enabling more accurate situational awareness, more consistent decision quality, and more adaptive strategic behavior – ultimately generating persistent and difficult-to-imitate competitive advantages.

Socio-technical theory, originating from the work of Trist and Emery, posits that organizational performance is contingent upon the co-evolution and mutual alignment of technological systems, social structures, human skills, workflows, and governance mechanisms. Within this theoretical frame, artificial intelligence significantly heightens the interdependence of these dimensions and amplifies the consequences of misalignment; advanced AI applications deployed within outdated organizational structures, inadequate skill bases, or rigid governance regimes generate systemic frictions that diminish performance and undermine competitive potential. Effective AI adoption therefore requires the coordinated alignment of data governance frameworks, ethical and normative constraints, human capital development,

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workflow redesign, and incentive structures that support experimentation and learning. Competitiveness does not arise from AI as an isolated technological asset but from its strategic and systemic integration into an organization's broader socio-technical architecture, wherein technology, people, processes, and governance evolve in concert to enable sustained value creation.

Within the dynamic capabilities framework, sensing, seizing, and reconfiguring constitute the core higher-order capabilities through which firms achieve and sustain competitive advantage in environments characterized by digital transformation and rapid technological change (Teece, 2007). Artificial intelligence substantially amplifies each of these capabilities. AI-enhanced sensing expands a firm's perceptual horizon by identifying weak signals, detecting emergent opportunities, and anticipating threats or environmental shifts through continuous, data-driven monitoring. AI-enhanced seizing strengthens managerial capacity to mobilize and deploy resources by optimizing allocation decisions, simulating strategic alternatives, and informing investment prioritization with high-resolution predictive analytics. AI-enhanced reconfiguring facilitates organizational adaptability by automating the reallocation of resources, enabling structural flexibility, and supporting the real-time restructuring of processes and workflows. When these enhancements are taken together, AI functions as a meta-capability that reinforces and accelerates the development of all lower-level dynamic capabilities, creating a hierarchical and self-reinforcing capability architecture that is difficult for competitors to replicate. Through this mechanism, AI becomes a fundamental driver of enduring competitive advantage in digitally intensive industries.

Institutional theory emphasizes that organizational behavior and performance are shaped not only by economic incentives but also by prevailing norms, regulatory structures, cognitive schemas, and legitimacy pressures. Consistent with North's (1990) conception of institutions as the formal and informal "rules of the game" that structure economic behavior and reduce uncertainty, artificial intelligence introduces profound institutional shifts by establishing new standards of efficiency and transparency, generating complex regulatory challenges such as GDPR compliance and algorithmic accountability, and creating heightened expectations regarding explainability, fairness, and ethical data governance. As institutional environments evolve in response to AI-driven transformations, firms that effectively navigate these emerging constraints and expectations gain what

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may be termed *institutional competitive advantage*: the ability to signal compliance, minimize regulatory exposure, and build stakeholder trust in an era of intensive algorithmic scrutiny. In this sense, institutional competence – encompassing regulatory literacy, ethical governance, and proactive legitimacy management – becomes a strategic complement to technological capability, enabling firms to deploy AI not only effectively but also in ways that are socially legitimate, institutionally aligned, and competitively differentiating.

From the perspective of platform economics, which conceptualizes digital markets as multi-sided environments characterized by interdependent user groups and strong network externalities (Rochet & Tirole, 2003; Hagiu & Wright, 2015), artificial intelligence plays a critical role in enabling firms to shift from linear value chains to data-intensive, ecosystem-based models of value creation. AI enhances the fundamental mechanisms through which platforms orchestrate interactions – such as participant matching, personalized recommendations, fraud detection, pricing optimization, governance of ecosystem participation, and large-scale data monetization – thereby improving platform efficiency and reinforcing user engagement (Evans, 2003; Parker, Van Alstyne, & Choudary, 2016). As these AI-driven capabilities amplify both direct and indirect network effects, platforms become increasingly susceptible to winner-take-most dynamics, market tipping, and heightened competitive concentration, outcomes widely documented in the platform competition literature (Gawer & Cusumano, 2014; Evans & Schmalensee, 2016). The result is a pronounced form of ecosystem competitive asymmetry in which early AI-enabled platforms accumulate disproportionate advantages, consolidate system-wide influence, and establish dominant positions that are structurally difficult for late entrants to contest.

Drawing on insights from behavioral economics, which emphasizes the systematic and predictable ways in which cognitive biases and bounded rationality shape organizational decision-making (Kahneman & Tversky, 1979; Simon, 1982; Thaler, 2015), artificial intelligence fundamentally reshapes firm competitiveness by reconfiguring the decision architectures, choice environments, heuristic triggers, and cognitive load under which managerial judgments are formed. By generating high-resolution predictive insights and processing information at scales that exceed human cognitive capacity, AI reduces the influence of common behavioral biases – including

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anchoring effects, availability heuristics, over-optimism, and loss aversion – that otherwise distort strategic assessment and resource allocation. Firms that embed AI into their decision environments thus construct behaviorally optimized organizational systems in which cognitive distortions are minimized, reaction times to environmental signals are accelerated, and forecasting accuracy is significantly enhanced. In this manner, AI becomes not merely an analytical tool but a transformative cognitive infrastructure that improves organizational rationality and strengthens competitive performance.

The frameworks reveal that AI reshapes competitiveness across multiple theoretical dimensions (Table 3.13).

Table 3.13. Synthesis: AI's Multi-Theoretical Competitive Advantage Architecture

Theoretical Lens	What AI Changes	Competitive Implication
Evolutionary economics	Variation - selection - retention speed	Faster innovation and adaptation
Complexity theory	Navigation of nonlinearity	Improved resilience, agility
Cognitive systems	Organizational intelligence	Superior decision-making
Socio-technical systems	Tech - human - structure alignment	Higher performance and lower friction
Dynamic capabilities	Meta-capability enhancement	Robust strategic flexibility
Institutional theory	Legitimacy and compliance	Reduced regulatory risk
Platform economics	Ecosystem coordination	Market dominance
Behavioral economics	Bias reduction	Optimized decisions

Source: created by author

This multi-theoretical synthesis provides the deep conceptual foundation. The table 3.13 integrates multiple theoretical lenses to demonstrate how artificial intelligence functions as a cross-cutting driver of competitive advantage. Each theoretical tradition contributes a distinct explanatory mechanism, yet collectively they form a coherent architecture that clarifies why AI produces such profound and asymmetric impacts on firms, industries, and economies.

From the perspective of evolutionary economics, AI accelerates the fundamental processes of variation, selection, and retention, enabling firms to innovate more rapidly, test more strategic alternatives, and institutionalize successful routines at scale. Complexity theory contributes by framing AI as a computational augmentation that enhances the firm's ability to navigate turbulent, nonlinear, and interdependent environments, improving adaptive fitness rather than simplifying underlying complexity. Through the lens of

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cognitive systems theory, the table highlights AI's role as an extension of organizational cognition, enhancing perceptual, interpretive, decision, and action capacities far beyond human limits.

Socio-technical systems theory underscores the importance of aligning AI with organizational structures, workflows, skills, and governance, emphasizing that competitiveness arises from the co-evolution of technological and social subsystems. In dynamic capabilities theory, AI appears as a meta-capability that strengthens sensing, seizing, and reconfiguring activities, reinforcing a hierarchical capability architecture that enhances strategic agility and organizational renewal. The institutional theory dimension demonstrates how AI reshapes normative, regulatory, and legitimacy environments, creating institutional constraints but also opportunities for firms capable of signaling compliance, ensuring ethical data use, and building trust.

Finally, the table incorporates insights from platform economics, revealing how AI amplifies network effects, data-driven coordination, and value co-creation within ecosystems, generating competitive concentration and enabling early movers to dominate multi-sided markets. Behavioral economics adds a further layer by explaining how AI mitigates cognitive biases, restructures decision environments, and improves the rationality of organizational decision-making.

Taken together, these theoretical perspectives illustrate that AI's competitive impact is not isolated or unidimensional; it is systemic, multi-level, and mutually reinforcing. The synthesis table thus provides a unified conceptual architecture showing how AI simultaneously enhances technological capabilities, cognitive capacity, organizational adaptability, institutional legitimacy, and ecosystem power. This multi-theoretical integration demonstrates that the firms most likely to achieve sustained competitive advantage are those that leverage AI across all these dimensions rather than restricting it to operational or analytical domains.

4. Mechanisms of AI-Driven Value Creation and Competitive Advantage. Artificial intelligence reshapes firm competitiveness not through a single technological pathway but through a constellation of mutually reinforcing mechanisms that operate at operational, tactical, strategic, and ecosystem levels. Understanding these mechanisms requires a shift from technology-centric explanations toward a mechanism-based, multi-level theory of AI-enabled value creation. Within this perspective, AI functions

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simultaneously as an efficiency accelerator, a predictive intelligence system, an organizational learning infrastructure, and a strategic transformation catalyst. Each mechanism contributes distinct competitive implications, producing cumulative and path-dependent effects over time (Table 3.14).

Table 3.14. Operational AI Mechanisms and Competitive Effects

Operational Mechanism	AI Functionality	Competitive Effect
Process automation	Algorithmic task execution across repetitive workflows	Structural cost reductions; productivity enhancement
Predictive analytics	Forecasting and probabilistic modeling	Reduced decision uncertainty; performance stabilization
Autonomous quality control	Computer vision - enabled defect detection	Lower defect rates; improved product reliability
Predictive maintenance	Sensor-based anomaly identification	Increased asset longevity; minimized downtime
Intelligent scheduling	Optimization via mathematical programming	Enhanced flexibility; responsiveness under constraints

Source: created by author

At the operational level, AI enhances efficiency by enabling cycle-time compression, error reduction, anomaly detection, and optimization routines that fundamentally alter baseline performance thresholds. These effects arise from the capacity of machine learning systems to identify patterns that elude human perception and to automate repetitive, data-intensive processes with high degrees of precision. Operational mechanisms produce the initial layer of competitive differentiation by shifting firms toward new productivity frontiers.

At the tactical level, AI augments decision-making processes by generating predictive and prescriptive insights that improve coordination, planning, and risk assessment. AI-mediated decision architectures increase the speed, granularity, and reliability of tactical judgments, thereby reducing uncertainty and stabilizing performance in volatile environments. This constitutes a second-order competitive mechanism centered on superior information processing and resource allocation.

At the strategic level, AI functions as a transformative capability that enables firms to redesign business models, restructure value propositions, and reconfigure strategic logic. AI-driven transformations – such as product-to-service transitions, intelligent product offerings, or platform orchestration – alter competitive boundaries and reposition firms within industry ecosystems.

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These mechanisms yield higher-order strategic advantages that are difficult for competitors to match due to their complementarity with organizational structures, data assets, and learning routines.

AI reshapes value creation at a more fundamental level by catalyzing the reconfiguration of business models, shifting the organizational locus of value from physical assets and traditional processes toward algorithmic intelligence, data assets, and adaptive service architectures. The transformation is neither uniform nor linear; instead, it occurs through analytically distinguishable archetypes that illustrate different degrees of technological integration and strategic change.

The AI-augmented model retains core human-led processes but enhances them through AI-based cognitive support (Table 3.15). This archetype emphasizes complementarity between human judgment and algorithmic reasoning, producing moderate but stable competitive gains.

Table 3.15. AI Business Model Archetypes and Competitive Implications

AI Business Model Type	Characteristic Features	Competitive Advantage Mechanism
AI-Augmented	Hybrid human - AI cognitive systems	Improved accuracy; higher productivity
AI-Automated	Algorithmic substitution of cognitive tasks	Radical cost efficiency; scalability
Intelligent Products	Embedded predictive and adaptive features	Differentiation; customer lock-in
Platforms	Multi-sided coordination enhanced by AI	Network effects; ecosystem power
Data Monetization	Data transformed into revenue streams	New value capture mechanisms
Autonomous Enterprise	Algorithmic governance and real-time process adaptation	Persistent agility; endogenous innovation

Source: created by author

The AI-automated model replaces human cognitive labor with algorithmic decision systems, generating radical cost efficiencies and enabling firms to scale operations without proportional resource expansion.

The intelligent product model embeds AI directly within goods or services, thus enabling adaptive functionality, predictive maintenance, and personalized user experiences. This archetype enhances differentiation and increases customer switching costs.

The platform model leverages AI to orchestrate interactions among multiple actors within digital ecosystems. AI becomes essential for

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coordinating participation, optimizing matching, preventing fraud, and enabling data monetization. The data monetization model transforms data into a primary economic asset, enabling firms to extract value through analytics-based services, insights, and predictive modelling. Finally, the autonomous enterprise model represents the apex of AI-enabled organizational transformation, in which AI becomes a core mechanism of governance, coordination, and continuous learning.

AI adoption produces heterogeneous sectoral outcomes due to differences in data intensity, automation potential, regulatory constraints, and technological complementarities (Table 3.16). Industry-specific competitive trajectories thus emerge as a function of structural characteristics that either amplify or restrict the deployment of AI capabilities.

Table 3.16. Sectoral AI Pathways and Sources of Competitive Advantage

Sector	AI Applications	Competitive Mechanisms
Manufacturing	Robotics, predictive maintenance, generative design	Efficiency frontier expansion; quality improvement
Finance	Algorithmic trading, risk analytics	Speed-based competition; precision and compliance
Retail	Recommender engines, dynamic pricing	Customer retention; supply-chain optimization
Logistics	Routing algorithms, autonomous vehicles	Reliability; cost minimization
Healthcare	Diagnostics, predictive care	Higher outcome quality; operational efficiency
Education	Adaptive learning systems	Personalization; scale economies

Source: created by author

In manufacturing, AI-enabled predictive maintenance, generative design, and robotic automation shift competition toward efficiency, reliability, and flexible customization. This results in a redefinition of production capabilities and the emergence of smart factories. In finance, algorithmic decision-making, fraud detection, and automated compliance reshape competitive criteria around speed, precision, and risk minimization. AI becomes central to market-making and operational governance. In retail, AI-driven personalization, inventory optimization, and dynamic pricing lead to deeper customer engagement and tighter integration of supply-chain processes. Competitive success increasingly depends on data-rich consumer profiling and real-time demand forecasting.

In logistics, routing optimization, fleet autonomy, and predictive

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logistics enhance efficiency and reliability, producing a structural shift toward real-time, data-driven coordination across geographically dispersed networks. In healthcare, AI improves diagnostic accuracy, accelerates clinical decision-making, and optimizes administrative operations. AI thus raises the quality frontier and reduces systemic inefficiencies. In education, adaptive learning systems and automated assessment enable scalability, personalization, and greater instructional precision.

The capacity to leverage AI effectively is shaped not merely by access to technology but by the presence of organizational capabilities that enable the assimilation, operationalization, and strategic integration of AI systems. AI maturity reflects a progression in which firms develop increasingly sophisticated socio-technical infrastructures, cultural orientations, and governance architectures.

At the initial stage, ad hoc adoption yields little competitive benefit due to limited integration and insufficient data readiness (Table 3.17). In the emerging stage, firms begin constructing data infrastructures and cultivating essential skills, generating modest gains. The integrated stage allows scalable AI deployment supported by robust data pipelines and cross-functional collaboration. In the optimized stage, AI becomes embedded in core workflows, enabling algorithmic decision augmentation and organizational agility. At the final cognitive enterprise stage, firms evolve into reflexive, continuously learning systems capable of real-time adaptation and autonomous coordination.

Table 3.17. AI Maturity Model and Organizational Requirements

AI Maturity Level	Technological Requirement	Organizational Requirement	Competitive Outcome
Ad Hoc	Isolated tools	Minimal strategic alignment	Insignificant performance gains
Emerging	Basic analytics; early data governance	Foundational data literacy	Incremental improvements
Integrated	Enterprise data architectures; ML pipelines	Cross-functional integration	Enhanced operational competitiveness
Optimized	Scaled AI systems; continuous deployment	Agile culture; adaptive routines	Strategic responsiveness
Cognitive Enterprise	Autonomous AI-driven systems	Learning-oriented governance	Sustained competitive leadership

Source: created by author based on (Gartner, 2020)

Table 3.17 presents a structured AI maturity model that conceptualizes

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the progression of firms' artificial intelligence capabilities as a sequential and cumulative developmental pathway. The model synthesizes insights from digital transformation theory, dynamic capabilities, and socio-technical systems scholarship to illustrate how technological sophistication and organizational readiness jointly determine the competitive outcomes associated with AI adoption. Each maturity level embodies a distinct configuration of technological infrastructure, organizational competencies, and strategic orientation, thereby generating qualitatively different contributions to firm-level competitiveness.

The Ad Hoc stage represents the lowest level of AI maturity, characterized by fragmented technological tools, absence of strategic coherence, and negligible integration into business processes. At this stage, the lack of data governance and organizational alignment prevents firms from achieving any substantive competitive advantage; AI remains experimental rather than transformative.

In the Emerging stage, firms begin to establish rudimentary data architectures and develop foundational forms of data literacy. Although AI deployment remains limited in scope, organizations start to build the absorptive capacity necessary for more sophisticated applications. Competitive effects are incremental, reflecting early operational improvements rather than strategic gains.

The Integrated stage marks a substantive shift in maturity: firms develop enterprise-wide data infrastructures, implement scalable machine learning pipelines, and cultivate cross-functional integration. AI becomes embedded in operational workflows, enabling systematic efficiency improvements and strengthening operational competitiveness. This stage reflects growing alignment between technological and organizational subsystems.

The Optimized stage reflects advanced AI assimilation. Firms operate agile organizational structures, leverage continuous deployment mechanisms, and develop adaptive routines that facilitate rapid strategic and operational realignment. AI is employed not only to improve efficiency but to enhance decision-making quality, responsiveness, and innovation. Competitive outcomes become more pronounced as firms acquire dynamic strategic advantages.

At the highest level, the Cognitive Enterprise, AI is not merely integrated into workflows but becomes a core mechanism of organizational coordination and continuous learning. Firms at this stage leverage autonomous systems,

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advanced reinforcement learning, and real-time data environments to reconfigure processes dynamically. Governance models are designed around learning orientation, algorithmic oversight, and systemic resilience. The competitive outcomes associated with this level are sustained and difficult to imitate, as the organization achieves the ability to adapt reflexively to environmental shifts, thereby securing long-term industry leadership.

Overall, Table 3.17 demonstrates that AI maturity is not a linear accumulation of technological assets but a multi-dimensional capability trajectory requiring simultaneous progress in infrastructure, skills, governance, and culture. Competitive advantage arises only when firms achieve coherence across these dimensions, illustrating the systemic nature of AI-enabled transformation.

Artificial intelligence introduces governance challenges that extend beyond technological implementation and into the institutional, regulatory, and normative domains that structure organizational behavior. AI-enabled firms operate within an institutional environment defined by formal mandates – such as data protection regimes, algorithmic accountability requirements, and sector-specific compliance frameworks – and informal expectations related to transparency, fairness, and ethical conduct. Consequently, AI governance becomes a multidimensional architecture encompassing model oversight, data stewardship, risk management, and ethical alignment rather than a narrow set of technical controls.

Institutional environments shape firms' strategic discretion by determining the boundaries of permissible data use, the nature of algorithmic transparency obligations, and the legitimacy required to deploy AI at scale. Countries and sectors with coherent, innovation-supportive regulatory frameworks create favorable conditions for firms to experiment, scale, and commercialize AI-enabled innovations, whereas fragmented or restrictive institutional contexts impose frictions that limit learning and investment. The strategic salience of governance thus lies in its role as a regulatory complement to technological capability, enabling firms to mitigate institutional uncertainty, reduce exposure to legal sanctions, and strengthen stakeholder trust.

Firms that internalize AI governance as a strategic capability – through practices such as algorithmic auditing, explainability protocols, adaptive compliance mechanisms, and ethical risk assessment – develop an institutionalized capacity to anticipate and align with evolving regulatory and

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normative expectations. Such institutional competence becomes a source of competitive advantage, particularly in industries where trust, legitimacy, and compliance are prerequisites for market access or continued operations. AI governance therefore functions simultaneously as a defensive mechanism that protects firms from institutional failures and as a proactive mechanism that enhances competitiveness by enabling responsible, scalable, and socially legitimate AI deployment.

AI's influence extends beyond firm boundaries to reshape competitive structures at both sectoral and national levels. At the sectoral level, AI adoption interacts with industry-specific characteristics – such as data richness, operational complexity, regulatory constraints, and capital intensity – to produce differentiated transformation trajectories. AI-intensive sectors such as finance, logistics, and e-commerce experience rapid restructuring driven by algorithmic decision-making, predictive analytics, and real-time coordination. In contrast, more regulated or infrastructure-dependent sectors, such as healthcare and public administration, undergo more gradual transitions shaped by institutional constraints and data governance challenges.

These sectoral transformations alter the competitive logic within industries by shifting key performance drivers from scale and cost-efficiency toward data advantage, algorithmic sophistication, and learning capacity. Industries increasingly converge around platform-based ecosystems in which value is co-created, shared, and monetized through AI-driven coordination mechanisms. This reorientation toward data-centric competition intensifies market concentration, promotes the emergence of dominant platforms, and increases the interdependence among firms participating in shared digital infrastructures.

At the macroeconomic level, AI functions as a general-purpose technology that catalyzes productivity growth, industrial upgrading, and structural transformation. Countries that invest heavily in computational infrastructure, data ecosystems, AI talent, and supportive regulatory frameworks position themselves advantageously within global value chains. Conversely, nations with limited digital infrastructure or restrictive institutional arrangements risk falling into AI capability traps, wherein insufficient resources hinder the ability to catch up to AI leaders, producing widening gaps in productivity, innovation capacity, and economic competitiveness.

AI also shapes geopolitical dynamics by shifting the sources of national

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power toward control of data, computational resources, algorithms, and digital standards. Competition increasingly revolves around the ability to set global norms for algorithmic governance, to dominate AI-enabled supply chains, and to establish technological sovereignty. As such, AI is not merely a technological artifact but a systemic factor that reorganizes the distribution of economic and strategic power across the international system.

Understanding AI-enabled competitiveness requires a multi-layered analytical framework that integrates micro-level organizational capabilities, meso-level industry structures, macro-level national ecosystems, and meta-level geopolitical dynamics. AI influences each of these levels through distinct but interrelated mechanisms, producing cascading effects that reshape competitive equilibria.

At the micro level, AI enhances firm competitiveness through automation, predictive intelligence, and decision augmentation, enabling efficiency improvements, innovation acceleration, and real-time adaptability. These effects emerge from the interplay between technological assets, organizational routines, and data governance practices.

At the meso level, AI reshapes industry structures by enabling platformization, ecosystem formation, and new forms of value co-creation. Industries transition from vertically integrated chains to digitally coordinated networks in which competitive advantage derives from orchestrating multi-sided interactions and leveraging network effects.

At the macro level, national competitiveness is determined by the extent to which countries can mobilize complementary institutional and infrastructural capacities – such as talent development systems, research ecosystems, digital infrastructure, and regulatory frameworks – to support broad-based AI diffusion.

At the meta level, AI redefines the strategic landscape of global competition by shaping technological dependencies, standard-setting power, and the ability of nations to exercise control over data flows and digital infrastructures.

The resulting multi-level architecture illustrates that AI-driven competitiveness is a function of systemic alignment across these layers. Firms and nations that develop AI capabilities in isolation – without corresponding institutional adaptation, governance capacity, or ecosystem integration – are unable to fully realize AI's competitive potential. Conversely, entities that coordinate these capabilities evolve toward AI-enabled competitiveness

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ISBN 978-9916-9320-3-2 (pdf)

regimes that are robust, adaptive, and difficult to replicate.

Conclusions. Artificial intelligence has emerged as a transformative force that reconfigures the foundations of business competitiveness across organizational, sectoral, and national levels. AI enhances operational efficiency, augments decision-making, supports business model innovation, and enables continuous learning within firms. At the industry level, AI catalyzes structural realignment, platform dominance, and ecosystem-based competition, reinforcing competitive asymmetries among firms and sectors. At the national level, AI serves as a driver of productivity, innovation, and global positioning, creating new forms of strategic interdependence and geopolitical rivalry.

The analytical synthesis of Parts I - III demonstrates that AI's competitive impact is neither isolated nor purely technological; it is systemic and path-dependent, shaped by technological capabilities, organizational architectures, institutional arrangements, and ecosystem dynamics. Sustainable competitive advantage in the AI era emerges from the alignment of these layers and from the development of dynamic, integrative, and reflexive capabilities that enable continuous adaptation.

Ultimately, AI is best understood not as a discrete technological input but as an embedded socio-technical meta-capability that reorganizes the cognitive, operational, and strategic foundations of economic activity. Firms and nations capable of mobilizing AI within coherent governance regimes, learning systems, and innovation ecosystems will shape the future contours of competition in the global economy.

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Chapter 4
Artificial Intelligence and Digital Transformation of Education

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Section 4.1. Integrated Economic and Information Security Frameworks for Multi-Level Learning and Web-Developer Recruitment in European IT Enterprises

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Abstract. *The study addresses the scientific problem of fragmented governance, where cybersecurity and economic stability are treated separately from human-capital development, resulting in preventable vulnerabilities, financial inefficiencies, and compliance failures. The objective is to demonstrate that developer competencies (secure coding, regulatory literacy, risk-aware decision-making, communication, and learning agility) function as key determinants of enterprise resilience in the European digital economy. The methodology is based on hypothesis-driven conceptual modeling supported by structured expert reasoning. Three authorial analytical models were developed using cybersecurity governance standards (GDPR, NIS2, Cyber Resilience Act), the European e-Competence Framework, HR analytics principles, and enterprise risk-mapping practices. Causal relationships between workforce competencies and enterprise-level economic and information-security outcomes were identified and operationalized into measurable indicators such as vulnerability density, cost of rework, incidents likelihood, and compliance exposure. The results reveal that secure recruitment and structured multi-level developer learning form an active defense system that reduces vulnerability exploitation, mitigates financial instability, and increases organizational resilience. The study advances the field by demonstrating how human-capital development translates into economic protection, linking secure workforce capabilities with improved cybersecurity investment efficiency and regulatory compliance. Limitations include a lack of econometric validation, absence of incident-level enterprise datasets, and contextual dependency on the EU regulatory ecosystem. Micro-firms or non-EU environments may demonstrate different competency–risk dynamics. These constraints indicate the need for future empirical and longitudinal studies. The findings serve as managerial guidance for integrating talent development into security governance, optimizing cybersecurity expenditures, and ensuring secure-by-design workforce formation aligned with digital-market expectations. The study introduces a novel unified framework linking recruitment, learning systems, economic efficiency, and cybersecurity readiness – an area previously researched only in fragmented form – thus offering new value for both academic scholarship and enterprise practice.*

Keywords: *economic security; information security; web-development workforce; digital skills; multi-level learning; enterprise*

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cybersecurity; European IT sector; human capital development.

1. Problem Background: Cybersecurity, Economic Resilience, and Developer Competence in the EU Digital Market. In the context of rapid digital transformation, European IT enterprises increasingly depend on complex web-based infrastructures to sustain competitiveness, deliver innovation, and protect strategic economic interests. At the same time, the accelerated use of cloud services, distributed architectures, and digital platforms has expanded the attack surface for cyber threats, making information security a core determinant of economic sustainability rather than merely a technical function. These two dimensions (economic security and information security) are often addressed separately within organizational structures, resulting in misaligned strategies, inefficient resource allocation, and increased vulnerability to both market volatility and cyber risks. Such fragmentation is especially evident in the sphere of web-developer recruitment and workforce development, where enterprises must ensure that newly hired specialists possess not only strong programming capabilities but also an applied understanding of cybersecurity and its economic implications. When these competencies are insufficient or uneven across development teams, the organization faces higher risks of code-level vulnerabilities, insecure system design, compliance failures, and ultimately severe financial losses.

The relevance of this research is reinforced by the ongoing shortage of qualified web developers in Europe, a trend confirmed by EU labor market forecasts, which indicate that digital economies are growing faster than the talent pipeline. Existing recruitment systems often focus primarily on candidate ranking by technical proficiency, omitting security awareness, knowledge of economic risk mitigation, and the ability to contribute to secure software development lifecycles. This leads to a critical skills mismatch: companies hire developers capable of building functional digital services but who may unknowingly introduce risks that undermine the organization's economic and information security posture. Meanwhile, cyberattacks, including ransomware, phishing intrusions, and data breaches, continue to intensify in scale and sophistication, disproportionately affecting small and medium-sized IT enterprises that cannot afford separate specialized security units. The failure to integrate economic and information security considerations in early stages of workforce formation magnifies these vulnerabilities and increases operational costs required to correct insecure

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systems post-deployment.

European IT enterprises acknowledge the need for holistic cybersecurity readiness, yet struggle to institutionalize it within organizational learning processes. Internal training programs often lack continuity, scalability, and multi-level instructional design tailored to the varied experience of developers – from junior specialists needing foundational cybersecurity skills to senior professionals requiring advanced risk-driven decision-making competencies. Traditional learning systems focus on compliance, imposing theoretical knowledge without emphasizing applied problem-solving in real development environments. As a result, knowledge remains unintegrated into daily web-development practices, and organizations maintain only a minimal level of cyber resilience rather than attaining proactive and economically informed security strategies. This gap highlights the necessity of innovative learning ecosystems that combine technical skills, security-by-design methodologies, and understanding of economic impacts related to cyber incidents.

Another central challenge concerns the absence of an integrated framework to support decision-making about cybersecurity investments in relation to staffing and skill development. Enterprises face uncertainties regarding how much to invest in secure development capabilities, what profile of specialists is economically justified for their architecture, and how improvements in human capital translate into measurable reductions of cybersecurity risk. When recruitment and educational strategies are disconnected from security and financial planning processes, companies may misallocate budgets – either overspending on tools while neglecting personnel training, or attempting cost-saving measures that later result in amplified threats and financial losses. Current models for cybersecurity investments, such as Gordon-Loeb-based economic approaches, are rarely adapted to workforce planning or incorporated into HR analytics for developer selection. As a consequence, the recruitment process does not contribute to building a security-aware culture and does not provide companies with reliable predictions regarding the economic returns of hiring decisions.

Additionally, the increasing reliance on automated or ranking-based selection systems in recruitment introduces further risks. Many existing digital hiring tools evaluate only limited sets of developer competencies, frequently excluding cyber-secure coding skills, threat modeling principles, or responsibility for protecting sensitive data. The absence of integrated, multi-criteria assessment frameworks contributes to biased or incomplete hiring

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outcomes that fail to support organizational resilience. Without clear methodologies to evaluate developer candidates against both technical requirements and security-critical behaviors, enterprises remain exposed to latent vulnerabilities that are difficult and costly to detect once embedded into operational web services.

The problem is exacerbated by the regulatory pressure imposed by European directives, including GDPR and the upcoming NIS2 Directive, which require organizations to demonstrate rigorous security and risk management standards across supply chains. When IT enterprises cannot ensure that their recruitment and training systems produce developers capable of meeting these standards, the companies face compliance penalties, market exclusion, and declining trust from consumers and partners. In this situation, strengthening the alignment between human resource strategies and integrated economic and information security objectives becomes a critical prerequisite for sustainable market development.

Therefore, the core problem addressed in this research is the lack of unified frameworks that simultaneously respond to economic security demands, information security imperatives, and workforce development needs in European IT enterprises. The existing separation of IT security planning from human capital strategies results in insufficiently secure web-development practices, inefficiencies in corporate spending on cybersecurity, and an underdeveloped culture of proactive threat mitigation. This disconnect threatens not only the technological integrity of digital services but also the economic resilience and competitive position of enterprises in the European market.

To overcome these challenges, there is a need for an integrated, multi-level learning and recruitment framework that equips web developers with the proper combination of skills and enables enterprises to assess and select candidates based on a holistic understanding of their potential contribution to economic and information security. Such a framework should ensure structured professional development, measurable improvements in secure design capabilities, and analytical decision-making tools that correlate investments in cybersecurity-oriented hiring with economic outcomes. Establishing this connection is vital because the stability of IT enterprises depends increasingly on internal human expertise that supports both innovation and protection of digital resources. The development and implementation of such integrated approaches will support European IT

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enterprises in building resilient development ecosystems, optimizing cybersecurity expenditures, and ensuring sustainable and secure organizational growth in an era of elevated uncertainty and expanding cyber threats.

2. Theoretical and Empirical Foundations: Secure Recruitment, Cybersecurity Economics, and Workforce Analytics. Integrated economic and information security frameworks are increasingly essential for IT enterprises operating within globalized digital markets, especially those that rely heavily on continuous recruitment and upskilling of web developers. European IT companies compete not only for high-performing technical talent but also for robust cybersecurity and sustainable economic security models that protect core digital assets and workforce data. As organizations accelerate digital transformation, talent management and security architectures become deeply interconnected, shaping strategic priorities for enterprise resilience. This review synthesizes academic contributions that explore intelligent recruitment technologies, economic–information security interdependencies, digital transformation in HR management, and cybersecurity investment optimization. Together, these strands illuminate both existing advancements and critical gaps in how enterprises develop secure multi-level learning ecosystems to ensure a competitive and resilient web-development workforce.

Yuskovych-Zhukovska and Bogut (2024) analyze the growing demand for structured, data-driven recruitment of web programmers. They propose an integrated intelligent information system that applies machine learning, automated skill matrices, and rank-based selection methodologies to enhance efficiency in hiring and professional development. Their model incorporates learning management systems, competency-based evaluations aligned with industry certifications, and continuous skill monitoring within corporate infrastructures such as CRM and Git repositories. The researchers highlight that developers' competence must encompass both technical proficiencies and soft skills relevant for distributed software teams. They show how automated systems can reduce recruitment time, increase matching accuracy, and improve developers' adaptation to enterprise projects. However, the authors place limited attention on information security requirements embedded in recruitment workflows, such as compliance with GDPR or secure management of candidate personal data. The research emphasizes technical automation but does not explore how such systems influence economic security outcomes, including risk mitigation related to turnover, talent

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shortages, or project delays. Additionally, broader European contextualization and cross-country validation remain underdeveloped, limiting generalizability beyond the Ukrainian IT labor ecosystem.

Dudka (2023) contributes to understanding how education shapes national resilience in environments characterized by hybrid threats and cybersecurity challenges. The author positions information literacy and cybersecurity education as foundational to economic stability, emphasizing that skill development strengthens the capacity of societies to withstand digital misinformation and cyber risks. Through a case study of the MediaStar platform, the paper illustrates how digital learning initiatives can promote responsible information practices, protect personal data, and develop cyber-aware workforces. The study suggests that collaboration among academia, private sector entities, and government organizations can generate widespread security benefits. Yet, the article remains conceptual and lacks empirical performance evaluation. It does not examine specific talent pipelines, recruitment strategies, or organizational-level upskilling mechanisms that IT enterprises require to sustain competitive advantages. The link between educational activities and quantifiable improvements in enterprise economic or information security is asserted but not supported by measurable data, limiting direct applicability to web-developer labor market demands.

Bilko (2023) examines systemic measurement of information security at the national level, situating it within the broader context of economic stability. The author identifies key security indicators that reflect strategic policy readiness, cybersecurity workforce training, personal data protection standards, and threat monitoring capabilities. Through correlation-regression methods, the study demonstrates that higher information security correlates with strengthened economic security, establishing a synergistic policy rationale for integrated governance. However, the analysis focuses on macroeconomic and regulatory structures without translating these findings to enterprise-level talent risks. For IT companies dealing with workforce shortages, intellectual property theft, and insider threats, security-based competency frameworks are necessary but absent from the model. The research overlooks how organizational recruitment strategies and developer upskilling requirements intersect with national cybersecurity indices. Therefore, its strategic insights underscore the need for further empirical operationalization at the enterprise scale, where hiring mismanagement can trigger economic and security vulnerabilities.

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Pravdyvets (2023) offers methods for analyzing digital transformation trajectories using cognitive information technology. The paper proposes the POLYHEDR platform, which structures weakly-organized enterprise data into actionable knowledge graphs to improve threat forecasting and enterprise security modeling. These approaches support classification of vulnerabilities, alignment of digital infrastructure with changing risk profiles, and informed decision-making processes. By emphasizing the dual function of digital tools – both as drivers of innovation and sources of increased exposure – the study captures the complexities IT enterprises face in balancing progress with resilience. Despite its analytical strength, the study does not address human capital frameworks or web-developer skills as components of economic security. The absence of workforce-related security indicators reinforces a gap between enterprise digitalization strategies and secure developer recruitment practices. Moreover, generalizability remains limited due to a focus on the Ukrainian technological environment and lack of multi-country validation.

Babichev and Samorodov (2023) advance a conceptual model for strengthening enterprise economic security through comprehensive assessment of information vulnerabilities. Their research defines economic security as a multidimensional construct requiring the protection of information flows that underpin productivity and competitive positioning. The proposed system leverages functional decomposition and hierarchical data models to map security responsibilities across business processes and identify areas of weakness. While this model offers a structured view of risk distribution, it lacks empirical testing and quantitative validation. The broad focus on generic industrial sectors limits insight into the specifics of software development environments, including knowledge leakage risks, secure coding standards, or developer onboarding processes. Human-factor vulnerabilities and internal behavioral threats are acknowledged implicitly but are not incorporated into model measurement. These limitations indicate that secure workforce management remains an underexplored component of economic and information security strategies.

Chornous and Gura (2020) analyze digital transformation within Human Capital Management, focusing particularly on predictive workforce analytics (WFA), business intelligence (BI), and cybersecurity tools that enhance managerial decisions. They argue that secure data-driven HR systems enable enterprises to forecast employee performance issues, strengthen retention strategies, and reduce operational uncertainty. The authors present several

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integrated security-analytics architectures that combine HCM systems with cybersecurity technologies, ensuring confidentiality and compliance in personnel data processing. Their conclusion emphasizes that enterprise resilience increasingly depends on the quality and security of HR analytics. Yet, the article does not differentiate between industry workforce structures; web-developer ecosystems operate with steeper mobility, freelance participation, and skill fragmentation, which require more adaptive models. The lack of explicit mention of EU-specific security regulations limits alignment with European enterprise practices. Predictive analytics is framed as beneficial for economic stability, but empirical tests confirming reductions in personnel-related economic losses are absent, signaling a gap for future quantitative validation.

Chubaievskyi, Blakyta, Bogma, Shtuler and Batrakova (2022) explore mathematical and algorithmic optimization for balancing security investments and potential economic losses from cyber incidents. They propose system-oriented models for determining optimal spending aimed at preserving enterprise resilience by analyzing threat probability and the severity of impacts on confidentiality, integrity, and availability. The framework includes integrated indicators of financial-economic, production, and organizational stability to evaluate how information threats influence enterprise dynamics. These methods reinforce that cybersecurity decisions must be resource-conscious and economically justifiable. However, the high technical sophistication may hinder managerial adoption in non-industrial sectors. The research does not address human-centric threats or skill-related vulnerabilities common in development teams, such as insecure coding practices, rapid staff turnover, and uneven expertise distribution. Its maritime-sector orientation limits relevance for digitally native IT enterprises whose core assets are intellectual capital and secure development workflows. Thus, workforce and educational components essential to secure enterprise performance remain unaddressed.

Harahulia, Suslov, and Horovoy (2023) shift attention to wartime and crisis conditions impacting enterprise economic security. Their findings show drastic reductions in industrial productivity, business continuity disruptions, and workforce contraction during the full-scale invasion of Ukraine. The authors propose a security management system incorporating financial, social, environmental, and information security sublevels as adaptive responses to uncertain environments. They contend that risk insurance, digital forecasting,

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and scenario modeling must complement traditional approaches to economic protection. Despite its relevance to external shock resilience, this article does not unpack how digital skill shortages affect enterprise recovery capacity. Web-development firms rely heavily on intellectual capital, and their economic security is directly tied to talent availability. The study's limited focus on workforce development, secure recruitment, and ongoing upskilling suggests substantial room to integrate human-capital considerations into economic security strategies. Also, the wartime context restricts generalization to the peacetime EU market, where cybersecurity compliance and talent competitiveness are primary challenges.

Franco, Omlin, Kamer, Scheid, Granville and Stiller (2024) bring attention to the economic logic of cybersecurity planning. They introduce SECAdvisor, a decision-support platform that evaluates the cost-benefit efficiency of cybersecurity investments using structured economic models. The system assesses digital asset value, threat likelihood, and control effectiveness while providing budget-constrained recommendations – helping companies invest wisely in cybersecurity to minimize financial loss exposure. User-testing confirms that professionals can apply the tool effectively to enhance planning and improve understanding of cybersecurity economics. The emphasis on financial optimization aligns with the need for web-development enterprises to allocate resources efficiently while protecting digital intellectual property and developer environments. Limitations include dependency on risk assessment quality, configuration accuracy, and data availability. The study does not explore integration with HR systems, which are increasingly targeted by cybercrime and ransomware attacks due to employee data centrality. Still, this research adds essential insights into aligning cybersecurity strategy with economic constraints and could be extended toward secure recruitment and training mechanisms.

Taken together, these studies reaffirm that economic security and information security are deeply interconnected domains, especially within digital-intensive industries such as software development. However, they also expose several thematic gaps. First, while recruitment automation models facilitate faster assessment and onboarding of web developers, these systems often omit comprehensive data protection protocols and economic loss considerations tied to poor talent fit or turnover. Second, national and enterprise-level security assessment frameworks seldom incorporate human capital readiness or secure talent-management models, despite skilled

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workforce shortages posing substantial strategic risks. Third, there is limited research integrating economic optimization tools with predictive HR analytics, despite strong evidence that personnel decisions influence enterprise resilience. Finally, studies rarely discuss how EU-level regulations – GDPR, NIS2 Directive, Cyber Resilience Act, European Digital Skills Agenda – reshape recruitment, skill validation, and data governance in IT labor markets.

Therefore, although existing research provides valuable theoretical and conceptual contributions across cybersecurity economics, digital workforce management, and enterprise resilience, a consolidated framework that explicitly merges secure recruitment, continuous developer learning, and enterprise economic stability remains undeveloped. There is a significant need for empirical analysis within European IT enterprises that evaluates how multi-level learning ecosystems, secure analytical HR systems, and cybersecurity-aligned recruitment strategies improve both economic outcomes and information security metrics. The present study addresses this gap by developing an integrative model and analytical evaluation that align economic security, information protection, and web-developer talent development as interdependent drivers of enterprise sustainability in the European digital economy.

3. Methodological Framework: Conceptual Validation of Integrated Risk–Learning and Compliance Readiness Models. The methodological foundation of this research is based on the hypothesis that secure recruitment and multi-level learning systems for web developers directly strengthen both information security and economic security of European IT enterprises operating in the digital economy. The central assumption is that professional competencies of developers represent a measurable determinant of vulnerability exposure, operational efficiency, and compliance-driven financial stability. The research aims to verify whether structured competency models and integrated workforce development practices reduce security incidents and economic losses associated with skill gaps, staff turnover, and regulatory non-compliance.

To test this hypothesis, the study synthesizes analytical data from three specially developed authorial frameworks: the Integrated Risk–Learning Framework, the Integrated Security–Economic Compliance Readiness Model, and the Secure Web-Developer Competency Model. These models were constructed using expert knowledge in cybersecurity, agile software

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development, and HR analytics. Publicly available documentation and statistical trends from European cybersecurity and digital-skills governance (GDPR implementation experiences, NIS2 and ENISA guidance, Cyber Resilience Act requirements, and the European e-Competence Framework) served as the informational base. These sources enabled the operationalization of the variables related to enterprise security capability, cybersecurity-driven workforce demands, and economic resilience.

The research applies a qualitative analytical approach supported by structured reasoning, mapping causal relationships between developer competencies, security exposures, and economic outcomes. Instead of collecting survey or experimental data, the study performs expert-model validation: risk categories, competency clusters, and maturity indicators are systematically cross-referenced to ensure internal coherence and external compliance alignment. The structured mapping allowed the identification of quantifiable performance markers such as vulnerability density, cost of rework, staff retention rates, fines and penalties risk, and secure-coding assessment scores, which anchor the model in measurable managerial practices.

The methodological workflow was executed in several iterative stages. First, a synthesis of risk typologies and learning interventions was conducted to define the baseline hypothesis and formulate the initial structure of Table 1. Second, the alignment between workforce development and enterprise-level resilience was examined, allowing the construction of Table 2 that translates competency maturity into specific economic and information-security impacts. Third, the talent-oriented defense architecture was elaborated further by developing Table 3, which integrates competencies with practical assessment mechanisms and demonstrates how learning systems mitigate identified risks. During each stage, the hypothesis was critically re-evaluated to ensure continuity: if a mapped relationship lacked empirical grounding or contradicted EU development standards, the model structure was updated accordingly.

Limitations of the study arise from the absence of quantitative enterprise-level datasets and the reliance on conceptual modeling rather than econometric testing. The results therefore represent a theoretical framework ready for validation in future empirical research involving cybersecurity investment data, developer-skill analytics, and incident-cost attribution. The models are also calibrated to the European regulatory ecosystem and may

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require contextual adjustment for IT enterprises outside the EU single digital market.

Despite these constraints, the methodology ensures logical consistency, transparent variable definition, and applicability to managerial decision-making. By linking workforce competencies with risk mitigation mechanisms and economic efficiency outcomes, the study provides a structured basis to test the hypothesis in real organizational environments. The developed frameworks contribute a strategic view of secure talent development as a key economic and information-security resource, confirming that the integration of multi-level learning into HR practices can significantly improve enterprise resilience in the evolving European cybersecurity landscape.

4. Model Development and Operationalization: Tables of Risks, Maturity Levels, and Competency Measurement. Table 4.1 captures critical vulnerabilities that European IT enterprises encounter at the intersection of economic performance, information security, and workforce development. In the digital economy, software development teams serve as both creators of value and potential sources of exposure. The risks presented in the table arise when developer competencies fail to align with evolving technological, regulatory, and security requirements. The framework positions multi-level learning systems as the fundamental mechanism through which enterprises can mitigate these risks while simultaneously improving operational efficiency, talent retention, and resilience to cyber threats.

Table 4.1. Integrated Risk–Learning Framework for Web-Developer Competency Gaps in European IT Enterprises

Risk Category	Description of the Issue	Economic Impact Indicators	Information Security Exposure	Multi-Level Learning Mitigation Strategy	Expected Outcome for IT Enterprises
Insufficient secure coding competencies	Developers lack practical knowledge of secure software design and vulnerability prevention	Cost of rework; increased project delivery time; budget overruns	Exposure to OWASP Top-10 vulnerabilities; exploitation of insecure code	Introductory and intermediate secure coding modules; onboarding bootcamps; supervised code review cycles	Reduction in exploitable security flaws; higher initial code quality
Obsolescence of technical skills	Knowledge gaps caused by legacy stacks, outdated frameworks, poor exposure to cloud-native or DevSecOps	Decline in productivity; lower market competitiveness; rising operational costs	Unsupported components increase attack surface; slower response to security threats	Continuous professional development; internal certification tracks; integration of new frameworks into learning paths	Faster adoption of secure technologies; improved workforce adaptability

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Risk Category	Description of the Issue	Economic Impact Indicators	Information Security Exposure	Multi-Level Learning Mitigation Strategy	Expected Outcome for IT Enterprises
	practices				
Fragmented cybersecurity awareness	Staff demonstrate weak understanding of privacy compliance, threat patterns, and secure data handling	Fines and penalties; disrupted service operations	Increased probability of phishing, insider breaches, and configuration errors	Mandatory cyber-hygiene courses; privacy-by-design training; simulated cyber-incidents	Stronger compliance posture; enhanced threat detection and reporting
High developer turnover and workforce instability	Competitive labor markets limit talent retention and erode accumulated project-specific knowledge	Higher recruitment and onboarding costs; reduced innovation continuity	Leaver-associated data leakage; unmanaged access risks	Career-path-based progression; mixed-seniority mentoring; personalized certification incentives	Stronger retention; reduced insider threat exposure; stable team composition
Limited collaboration between HR and IT-Security functions	Competency assessment ignores security dimensions of development work	Misallocation of labor resources; inefficient personnel planning	Role misfit leads to insecure implementation practices	Integrated skills matrix based on job-security requirements; joint HR-SecOps evaluation	Aligned recruitment and security goals; optimized allocation of competencies
Underutilization of automated evaluation systems	Manual hiring assessments increase bias and slow detection of security-relevant skill gaps	Longer hiring cycles; increased hiring errors	Lack of verification of candidate honesty and secure coding skills	AI-support screening, code quality metrics, LMS-GitLab synergy	Faster, more objective hiring; improved accuracy in screening skills relevant to security

Source: elaborated by the author

The first risk category emphasizes secure coding as a foundational competence. Many enterprises continue to prioritize delivery speed and commercial functionality at the expense of proactive vulnerability prevention. This creates measurable economic inefficiencies, including repeated cycles of patching, unplanned remediation costs, and reduced customer trust due to quality failures. The presence of common vulnerabilities, such as SQL injection or cross-site scripting, directly correlates with skill insufficiencies. Multi-level secure coding programs, beginning at onboarding and continuously reinforced through code review and peer learning, form a targeted mitigation pathway. These programs improve the "first-time-right" rate of code, reducing both attack surfaces and project overspend.

Obsolescence of technical skills forms the second risk dimension. Cloud

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technologies, containerization, and DevSecOps automation evolve rapidly; however, many developers remain anchored to outdated frameworks or limited to on-premises paradigms. When core skills stagnate, productivity declines, integration of protective technologies slows, and dependency risks increase. A structured progression system reinforced by internal certifications and continuous learning ensures that teams adapt quickly to secure architectures. This supports economic growth by preserving competitive advantages and prevents vulnerabilities linked to deprecated components.

The third item addresses cybersecurity awareness as a holistic organizational behavior rather than an isolated skill. Even proficient developers may mishandle personal data or underestimate the risk posed by misconfigurations and phishing attempts. Economic consequences include regulatory penalties and operational downtime. By embedding cyber-hygiene and compliance training into mandatory learning levels, enterprises improve not only individual behavior but also systemic risk management. Simulated cyberattacks reinforce threat recognition, supporting a more resilient defense posture.

Turnover-induced instability, the fourth category, is particularly acute in the European IT labor market, where skilled developers are highly mobile. Each departure represents lost knowledge, project delays, and increased exposure through overlooked access rights. When secure recruitment and multi-level learning systems are combined, employees perceive clear career trajectories and specialization opportunities, improving retention incentives. Lower staff churn correlates with higher codebase familiarity, reducing implementation mistakes and preserving tacit cybersecurity knowledge.

The fifth risk highlights internal fragmentation between HR and security functions. Traditional recruitment strategies frequently focus on general technical proficiency without assessing security integration skills or awareness of regulatory frameworks. As a result, enterprises may unintentionally elevate individuals lacking competence in essential secure practices. A unified competency matrix that explicitly links development tasks to regulatory and security requirements ensures that hiring decisions align with organizational safety priorities. This interdisciplinary synergy strengthens both economic performance and security governance.

Finally, the underutilization of automated evaluation tools reflects a longstanding challenge in IT recruitment. Manual assessment is subject to biases and often fails to detect latent weaknesses in candidate coding

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performance. Intelligent recruitment platforms, integrated with learning management systems and version-control repositories, make it possible to evaluate secure coding behavior dynamically and continuously. By accelerating screening processes and increasing accuracy, automation contributes directly to economic efficiency and reduces the likelihood of placing unsuitable candidates in critical development roles.

The Integrated Security–Economic Compliance Readiness Model presented in Table 4.2 reflects a multidimensional maturity framework combining: enterprise economic stability; cyber-information protection practices; secure and structured recruitment of web developers; and alignment with EU regulatory frameworks and skills policies.

Table 4.2. Integrated Security–Economic Compliance Readiness Model for IT Enterprises

Maturity Level	Strategic Focus	Recruitment & Workforce Development	Information Security Capabilities	Economic Security Indicators	Alignment with EU Frameworks (Examples)
Level 1 – Initial / Fragmented	Reactive survival operations	Ad-hoc hiring; no competency model; reliance on freelancers	Minimal cybersecurity measures; outdated tools; no access control	Frequent disruptions; vulnerability to fraud; high financial losses	Low compliance with GDPR, NIS2; basic awareness only
Level 2 – Basic Protective Adoption	Tactical protection of core assets	Job descriptions exist but lack skill depth; limited vetting; basic onboarding	Antivirus, basic firewalls, initial IAM setup; compliance is checklist-driven	Unpredictable cash flow; occasional disruptions; early risk monitoring	Partial alignment with GDPR Article 32; minimal CRA-related secure-development practices
Level 3 – Structured & Skills-Oriented	Workforce upskilling to reduce operational risk	Competency matrices defined; multi-level learning paths for developers; internal LMS	Secure SDLC practices emerging; role-based access; vulnerability scanning	Controlled losses; cyber insurance in place; cost-benefit monitoring	ENISA Secure ICT guidance applied; alignment with e-CF levels e-1 to e-3
Level 4 – Data-Driven Integration	Predictive risk mitigation	Predictive analytics for recruitment; automated skill evaluation; integrated HR–IS dashboards	Threat intelligence, SIEM, continuous compliance audits; secure cloud	Optimized resource allocation; resilience planning; reduced OPEX losses	Strong compliance with NIS2, GDPR DPIA, ISO/IEC 27001 integration
Level 5 – Strategic Security-Economics Leadership	Security-driven competitive advantage	EU-aligned credentialing (e-CF 4–5), continuous security-competence assessment, automated	Zero-trust architectures; AI-driven SOC; proactive red-teaming culture	Cost-efficient growth; cybersecurity investment optimized to reduce systemic risk	Full integration with EU Cyber Resilience Act, ENISA Cyber Skills, Digital Europe standards

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		mobility of talent			

Source: elaborated by the author

This unified maturity approach addresses a prominent gap in existing scholarship: most studies explore economic security, information security, or workforce competence in isolation, while modern digital enterprises require a holistic integration of all three domains. Particularly in the European IT labor market, secure recruitment and multi-level workforce learning must align with strategic cybersecurity compliance and cost-efficiency expectations arising from GDPR, NIS2 Directive, the Cyber Resilience Act, and evolving ENISA guidance.

Organizations at the lowest maturity level operate reactively, often without defined roles or skill requirements. Recruitment depends on availability rather than security-critical competencies. Economic losses emerge from cyber incidents, inefficient project staffing, and poor scalability. Data privacy compliance is accidental rather than intentional. Newly formed web-development startups typically fall in this category, where human-factor vulnerabilities become the most exploited attack vector. The table emphasizes that maturity upgrade at this level begins with strategic planning, role definition, and minimal security-by-design awareness.

At Level 2, basic cyber protections appear, usually motivated by client requirements rather than proactive strategy. Hiring processes remain superficial, failing to validate coding security skills, leaving enterprises exposed to software supply chain risks. Outreach for talent is often cost-driven, with insufficient onboarding or continuous learning frameworks. Economic indicators still show instability, though early improvements in monitoring and risk recognition appear. This maturity level often represents SMEs pressured by compliance but lacking security-economics literacy. Transition to Level 3 requires structured skills architecture and secure development workflows.

At Level 3, human capital development becomes a security enabler. Enterprises start using competency matrices (e.g., aligned to the European e-Competence Framework) and role-specific profiling to recruit web developers more strategically. Learning Management Systems (LMS) introduce multi-level learning paths (i.e., trainee–junior–middle–senior–lead). Security shifts left into the development process via secure coding checklists, vulnerability scanning, and basic DevSecOps integration. Economically, incidents become more predictable and preventable, enabling initial resilience planning and

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cyber insurance adoption. Table 2 positions this level as the foundation where talent management decisively merges with information-security capabilities.

Level 4 marks the shift toward predictive capability. Process automation enhances both recruitment efficiency and risk mitigation. Intelligent information systems support: real-time skill evaluation; workforce analytics for attrition and productivity; integration of HR systems with SIEM and compliance dashboards.

Security and economic governance become intertwined: investments are measured for return in reduced damages and higher operational continuity. EU-wide compliance expectations inform development practices, including Data Protection Impact Assessments (DPIA) and secure cloud architectures required under NIS2. This maturity level reflects scalable, export-ready IT enterprises within the EU single digital market.

At Level 5, organizations demonstrate security-driven competitive advantage: zero-trust architectures, red-teaming cultures, and continuous developer certification ensure a highly resilient environment. Recruitment aligns with the highest levels of the e-Competence Framework (e-CF 4–5), facilitating pan-European talent mobility. At this stage, cybersecurity investments are optimized via economic-model validation, and enterprises contribute knowledge back to industry and regulatory innovation.

Table 4.3 operationalizes a competency architecture that integrates information security and economic security into core expectations for web developers across their career progression. The model is premised on the idea that talent development and recruitment are not only technical HR functions but also strategic security assets that directly influence enterprise resilience, cost efficiency, and regulatory compliance in the European digital ecosystem.

The proposed framework introduces five interdependent competency categories: secure technical abilities, cybersecurity compliance awareness, project and risk management skills, collaborative communication culture, and continuous learning. These components connect human capital performance with both cybersecurity defense capability and business continuity objectives – critical attributes for IT enterprises navigating intensifying cyber threats and talent scarcity.

The first group reflects technical proficiencies aligned with OWASP guidance, secure data handling, authentication design, and repository governance. These competencies mitigate the introduction of exploitable weaknesses into products – an essential requirement as software supply-chain attacks increase across Europe. Failure in this domain not only generates remediation and downtime expenses but also causes severe compliance penalties under GDPR and the forthcoming EU Cyber Resilience Act.

Table 4.3. Secure Web-Developer Competency Model Linking Information and Economic Security

Competency Category	Specific Competencies	Role Relevance Across Grades	Information Security Contribution	Economic Security Contribution	Measurement / Assessment Methods
1. Secure Technical Skills	Secure coding (OWASP Top-10), version control discipline, API security, data protection design	High relevance for all roles (Trainee → Lead)	Reduces vulnerabilities, prevents data breaches	Minimizes financial losses and downtime; avoids regulatory fines	Code review score, secure-coding certifications, vulnerability density metrics
2. Cybersecurity Awareness & Compliance	GDPR/NIS2 literacy, secure handling of credentials, incident reporting	Required across all roles; critical for mid-senior engineers	Ensures compliance with EU cybersecurity frameworks	Protects against penalties and preserves customer trust	Training completion logs, simulated phishing tests, compliance exams
3. Project & Risk Management Skills	Task estimation, secure design decision-making, cost-risk balancing	Stronger expectations at middle+ roles	Improves secure architecture planning and risk mitigation	Optimizes cybersecurity investment, reduces rework cost	Scenario-based evaluation, sprint retrospectives, project risk scoring
4. Team Collaboration & Communication	Secure communication practices, conflict prevention, stakeholder negotiation	Essential for junior → lead roles	Supports accountability and controlled information sharing	Reduces coordination costs; improves project delivery stability	360° feedback, communication quality scoring, role-play assessments
5. Continuous Learning & Innovation	Adapting to new threats, proactive skill upgrading, certification pathways	Key for senior and lead roles	Enhances enterprise resilience with evolving defenses	Sustains productivity and talent retention; competitive differentiation	LMS analytics, upskilling roadmap completion, innovation contribution index

Source: elaborated by the author

Most literature treats cybersecurity awareness merely as an IT-security initiative. Table 4.3 reframes it as an economic survival requirement. Developers serve as custodians of personal and confidential corporate data, making them responsible for first-line compliance with GDPR Article 32, NIS2 governance obligations, and certification-based cyber hygiene. Thus, literacy in reporting protocols, access control discipline, and regulatory implications becomes crucial for preventing costly legal incidents. These competencies expand the security perimeter to include behavioral compliance,

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which is essential for European IT companies working across borders.

The third category introduces cost-security optimization skills, such as effort estimation, secure architecture evaluation, and the ability to translate security requirements into budget-aligned decisions. Developers are increasingly expected to participate in risk scoring during agile planning ceremonies. Integrating these analytical abilities into recruitment helps ensure that security is not treated as emergent rework, but strategically managed within project economics. Measurable outcomes include: reduction in unplanned spending linked to security fixes; more predictable delivery of secure features; increased ROI in cybersecurity investments; through this category, the model maintains security as a value-driven governance practice.

Economic security depends not only on protection from attackers but also on internal information-processing efficiency. Table 3 emphasizes collaborative communication skills, including secure data sharing within teams and with stakeholders. These competencies help prevent operational misalignments leading to costly project overruns, as well as insider threats, which are known to cause up to 30–40% of cyberbreaches in SMEs. Internal transparency paired with role-based access helps safeguard commercial secrets, intellectual property, and sensitive customer requirements.

Due to fast-evolving cyberattack vectors, skill obsolescence imposes direct economic risk. The fifth competency category positions learning agility and innovation behavior as long-term strategic differentiators. EU initiatives such as Digital Europe, the Cyber Skills Academy, and ENISA awareness strategies underscore the importance of continuous professional development to maintain market competitiveness and operational resilience. For senior engineers and leads, innovation tracking and proactive contributions, such as secure coding accelerators or DevSecOps tooling improvements, bolster sustainability and cost-effectiveness of enterprise architectures.

The measurement column operationalizes the model through: vulnerability reduction indicators; incident-response simulation performance; secure-coding certification path completion; 360° communication feedback analysis; learning analytics from LMS ecosystems. Such metrics are necessary for linking security performance to workforce investment returns. This quantification capability directly fills a literature gap by showing how HR development data inform risk management and financial planning.

5. Implications for Research and Practice: Integrating HR Analytics with Cybersecurity Economics. The findings of this study reinforce the

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central claim emerging from contemporary scholarship: information security and economic security within IT enterprises are deeply dependent on workforce competence. Prior studies acknowledge components of this relationship yet often treat them in isolation. For instance, intelligent recruitment research has demonstrated how automated assessment improves candidate–job fit and accelerates screening processes (Yuskovych-Zhukovska & Bogut, 2024) but did not operationalize how secure technical competencies prevent financial or cybersecurity harm. The present research directly extends those arguments by demonstrating that shortcomings in secure coding, regulatory literacy, or collaborative communication create immediate economic vulnerabilities through rework costs, fines, downtime, and intellectual property exposure. Thus, secure talent development emerges not merely as an HR function but as a strategic economic safeguard.

The results also align with studies emphasizing the role of digital education in strengthening national resilience to cyber threats (Dudka, 2023). However, whereas prior work largely examined educational systems from a societal perspective, this research translates those insights to the enterprise level, showing that targeted multi-level learning interventions – particularly when embedded into developer workflows – serve as an active defense mechanism reducing threat exploitation and economic instability. In this way, the current study fills a critical gap by connecting educational interventions directly with measurable organizational risk mitigation.

Macro-level analyses of information–economic security interdependence (Bilko, 2023) established a correlational foundation but lacked actionable mechanisms explaining *how* security capabilities translate into enterprise stability. Here, the results reveal that developer competencies function as the operational conduit between national cybersecurity policy expectations and business continuity. While earlier frameworks focused on state readiness metrics, this study shifts the lens to the micro-economics of cybersecurity: the talent decisions inside development teams that determine whether regulatory obligations and security objectives are fulfilled in practice.

Similarly, prior research on digital transformation in enterprise security (Pravdyvets, 2023; Chornous & Gura, 2020) illuminated infrastructure and analytics as key resilience drivers. The findings of this study complement these insights by demonstrating that predictive analytics and secure digital tools require a workforce trained to interpret, apply, and sustain them. Technology-centric approaches alone cannot ensure resilience if skill

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obsolescence and turnover continue to fuel preventable risk exposure. This research therefore positions workforce security competence as the enabling architecture for effective cybersecurity investment – an important refinement to existing economic-optimization models (Chubaievskyi et al., 2022; Franco et al., 2024).

Despite these contributions, several limitations must be explicitly addressed. Firstly, the research relies on conceptual modeling and structured expert reasoning rather than econometric evidence or incident-level data from enterprises. As a result, causal claims about economic outcomes, such as reductions in costs or compliance penalties, remain theoretically grounded but not yet statistically verified. Second, the focus on European regulatory and labor-market environments means findings may not fully generalize to regions where security mandates or market dynamics differ substantially. Third, the enterprise archetype assumed in this study reflects organizations with sufficient maturity to deploy analytics-enabled HR systems; micro-firms or rapidly shifting startup environments may display divergent relationships between learning, competency development, and security governance. Finally, human factors such as motivation, team culture, and behavioral unpredictability may moderate the relationships proposed here, suggesting the need for future mixed-methods studies.

6. Conclusions. The purpose of this study was to develop an integrated framework that simultaneously addresses economic security, information security, and workforce development in European IT enterprises, with a specific focus on web-developer recruitment and multi-level learning. The underlying scientific hypothesis stated that secure recruitment and structured, multi-level learning systems for web developers directly strengthen both information security and economic security. Based on the conceptual modeling and structured analytical reasoning undertaken, this hypothesis is confirmed at a theoretical level.

The research demonstrates that developer competencies are not merely an operational parameter but a core determinant of vulnerability exposure, regulatory compliance, and cost stability. By systematically linking secure coding skills, cybersecurity awareness, risk-sensitive project management, collaborative communication, and continuous learning to measurable indicators such as rework costs, incident likelihood, downtime, and penalties risk, the study shows how human capital becomes an active security and economic asset. The results clarify that fragmented treatment of HR,

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cybersecurity, and financial planning leads to misaligned incentives, inefficient budget allocation, and persistent exposure to avoidable cyber threats.

A key added value of this work is the consolidation of previously disconnected strands of scholarship (intelligent recruitment, national information security indices, digital transformation in HR, and cybersecurity investment models) into a single integrative perspective. The study reframes web-developer recruitment and learning not as auxiliary HR processes but as structural levers for building security-by-design cultures, improving return on cybersecurity investments, and aligning enterprise practices with EU-level regulatory requirements (GDPR, NIS2, Cyber Resilience logic, and the European digital-skills agenda). By identifying competency-linked performance markers, it also provides a basis for embedding security-oriented criteria into HR analytics, workforce planning, and strategic budgeting.

The findings have several policy and managerial implications. For European IT enterprises, they underscore the necessity of treating developer learning ecosystems as part of the core security and economic strategy rather than discretionary training expenditure. For regulators and policymakers, the results suggest that skills and competency requirements should be more explicitly integrated into cybersecurity and economic security frameworks, including guidance on secure software development, skills taxonomies, and targeted support for SMEs that lack specialized security units. At the ecosystem level, closer coordination between labor-market initiatives and cybersecurity policy could help mitigate the structural shortage of security-competent developers that currently undermines the resilience of the European digital economy.

At the same time, the study's limitations point to clear directions for further research. Future work should empirically validate the proposed relationships using enterprise-level data on security incidents, financial losses, recruitment practices, and learning outcomes across different EU countries and firm sizes. Mixed-methods studies combining surveys, incident analytics, and case studies would allow testing causal pathways between competency development, security performance, and economic results. Longitudinal evaluations of organizations that implement integrated, security-oriented recruitment and learning systems would further refine the model, enabling more precise quantification of the economic benefits of secure human-capital strategies in European IT enterprises.

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Section 4.2. Strategic Analysis of Sustainable Development of Higher Education Institutions in the Face of Digitalization Challenges

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***Abstract**. Ukrainian higher education institutions operate in a highly volatile environment shaped by digitalization, economic instability, demographic decline, and persistent external threats. Ensuring their sustainable development therefore requires systematic strategic analysis that captures environmental complexity, institutional constraints, and long-term transformation challenges, rather than relying on linear planning models. This chapter aims to provide a comprehensive strategic assessment of HEIs' sustainable development in Ukraine by identifying key external factors, examining their interactions, and substantiating adaptive development strategies under uncertainty. The methodological framework combines PEST analysis of the macroenvironment, cognitive modelling with fuzzy cognitive maps, expert evaluation with consensus testing via Kendall's coefficient of concordance, and SWOT analysis. The empirical base includes expert surveys involving representatives of academia, university management, and public administration, supplemented by case studies of universities with different ownership forms. The results show that political and economic factors exert the strongest influence, particularly regulatory instability, funding constraints, inflationary pressures, and demographic trends. At the same time, technological and socio-cultural factors, especially digital transformation, internationalization, and changing educational demand, provide notable development potential. Cognitive modelling confirms that external drivers interact in complex, mutually reinforcing ways, with combined effects outweighing isolated influences. SWOT analysis reveals substantial differentiation in institutional capacities and supports differentiated strategies, including integration-oriented growth, diversification, vertical integration, and crisis-adaptation pathways. Overall, sustainable development of Ukrainian HEIs depends on integrating digital transformation with institutional adaptation, strategic flexibility, and alignment with the European Higher Education Area.*

***Keywords**: higher education institutions; sustainable development; strategic analysis; PEST analysis; cognitive modeling; SWOT analysis; digital transformation; external environment; Ukraine.*

1. External environment impact on education: the political, economic, social, and technological factors influencing the development of Ukrainian HEIs. Sustainable development is a global imperative that reflects the vector of development of the world community and contributes to a comprehensive solution to environmental, social and economic challenges. The concept of sustainable development is aimed at ensuring balanced and long-term socio-economic growth, focused on improving the well-being of the population and the efficient use of resources.

The United Nations has defined global sustainable development goals (SDGs), including ensuring quality education and encouraging lifelong learning, ensuring decent work and economic growth, full and productive employment and decent work for all, creating the necessary sustainable infrastructure, promoting innovation, a global partnership for sustainable development and revitalizing its activities. Higher education institutions are centres that play a key role in achieving the specified goals of sustainable development by training specialists who are able to respond to the global challenges of today, implementing innovative educational programs, conducting interdisciplinary scientific research and developing public-private partnerships at the national and international levels, transferring knowledge and technologies, and cultural and educational activities. Therefore, it is HEIs that become catalysts of changes aimed at ensuring the environmental responsibility of society, social justice and economic sustainability.

Research on the management of sustainable development of HEIs in Ukraine occupies an important place in the scientific works of the domestic academic community. A significant number of works by Ukrainian scientists who analyze the role of higher education in ensuring the sustainable development of the country and the implementation of European standards in the educational process and management practices of universities are devoted to this issue. In particular, Lyashenko (2010; 2020) analyzes the sustainable development of HEIs through the prism of local information and communication aspects. Ilnytskyi & Sandul (2017) in their research study areas of study that will ensure that higher education students acquire "sustainable development" competencies. In turn, Tunytsia et al. (2019) propose the creation of sustainable universities through the systematic integration of sustainable development principles into all areas of activity.

The influence of the external environment on the development of HEIs is extremely important. HEIs must adapt to changes in the political, economic,

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social and technological environment in order to remain relevant and competitive. Taking into account the influence of the external environment allows HEIs to develop development strategies that meet modern challenges and ensure their adaptation to change. This contributes to improving the quality of education, competitiveness and sustainability of universities.

Today, there are certain problems in determining the impact of the external environment on the development of HEIs. In terms of assessing the impact of political factors, there is insufficient consideration of the impact of international political changes on the development of higher education, which results in the lack of effective mechanisms for adapting to changes in state policy and regulatory requirements (Buhlai et al., 2023). Also, insufficient research on the impact of global economic crises on the financing and sustainability of HEIs entails the lack of HEI strategies to ensure financial stability in conditions of economic instability, which is also facilitated by insufficient consideration of the impact of demographic changes on the demand for higher education and the structure of the student audience and the lack of research on the impact of social changes on educational programs and teaching methods (Kubitskii et al., 2023). In turn, insufficient research on the impact of rapid technological development on teaching methods and HEI management leads to the lack of strategies for integrating new technologies into the educational process and management.

To study the impact of the external environment, namely its main factors, on the development of HEIs, it is advisable to apply, first of all, the PEST analysis methodology, which allows studying four main groups of external environmental factors: economic, legal, technological and socio- cultural. PEST analysis is an excellent tool for assessing the impact of the external environment on the development of HEIs.

Political influence is exercised through the influence of state policy on the development of higher education and the role of international relations in the development of higher education.

Economic influence is exerted by economic factors that affect the financing of higher education institutions, as well as the impact of global economic trends on higher education.

Social changes and their impact on the demand for higher education, as well as the impact of demographic changes on higher education, belong to the group of social factors of influence.

Also, the sustainable development of HEIs is significantly influenced by

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technological innovations that have a direct impact on teaching methods in higher education and determine the role of information technologies in the development of HEIs.

Economic factors, such as government funding, grants, and investments, directly affect the development opportunities of HEIs. Changes in the economic environment can affect the availability of resources. Political stability is key to ensuring the continuity of the educational process (Vlasyuk&Ustik, 2024; Tunytsia, 2024; Khovrak, 2019).

Demographic changes, cultural trends and social changes are affecting the demand for higher education, the structure of the student body and educational programs. Higher education institutions must take these changes into account to meet the needs of students.

The development of new technologies is changing the methods of teaching, research and management of HEIs. The integration of modern technologies is important for improving the quality of education and the efficiency of management (Widyasari, 2019). Taking into account environmental aspects and social responsibility is important for ensuring the sustainable development of HEIs. This includes the introduction of environmentally friendly technologies and the support of socially responsible initiatives (Vlasyuk&Ustik, 2024; Tunytsia, 2024; Khovrak, 2019).

Table 4.4 lists the main factors of the external environment of the functioning of HEIs and identifies the directions of their influence.

It is worth considering that the factors of each group influence each other, forming interrelationships. This indicates that all factors taken into account in the PEST analysis can be represented in the form of a fuzzy cognitive map (FCM) for further analysis through a cognitive approach.

Within the framework of macro-level management, the cognitive approach to modelling and management is focused on creating formal models and methods that take into account the cognitive capabilities of management entities (such as perception, representation, cognition, understanding and explanation) when making decisions in solving management tasks. The cognitive map is built on the basis of subjective perceptions of experts about the situation.

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Table 4.4. The main factors influencing the external environment on the development of Ukrainian higher education institutions

Group of factors	Factors	Areas of influence
Political	Public policy	Changes in public policy may affect HEI funding, such as research grants
	Regulatory changes	New laws and regulations may require additional resources to ensure compliance with standards
	International relations	Relations with other countries can affect opportunities for international cooperation and student exchange.
Economical	Economic climate	Economic crises can negatively impact investment in higher education
	Energy costs	Rising energy prices may reduce funding available for other initiatives
	Public-private partnership	Creating clusters will contribute to increased funding
Social	Demographic changes	Changes in the demographic composition of the population can affect the demand for higher education
	Cultural trends and value system	Cultural changes can affect educational programs and teaching methods
	Social changes	Changes in society can affect the structure of student audiences and educational programs
Technological	Technological factors	The development of new technologies can change teaching methods and the management of higher education institutions.
	Digital technologies	The use of digital technologies can increase the efficiency of teaching and research.
	Information systems	Information systems can improve the management of HEIs.

Source: developed by the authors based on (Vlasyuk&Ustik, 2024; Tunytsia, 2024; Khovrak, 2019)

The system of concepts of the external environment of the higher education sector of Ukraine, built based on the results of interviews with experts in the field of higher education - scientific and pedagogical workers of HEIs (8 people, including 4 members of the National Agency of Quality Assessment), deans of faculties (2 people), an employee of the Department of Higher Education and Adult Education of the Ministry of Education and Science of Ukraine is given in Table 4.5.

Assess the impact of each macroenvironmental factor on the development of higher education in Ukraine on a scale of “agree-disagree” with each statement and assess the degree of impact of each factor on the development of higher education on a 10-point scale, where 1 is the lowest score, 10 is the highest score.

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Table 4.5. System of concepts of the external environment of higher education institutions of Ukraine

Concept group	Concept symbol	Concept name	Impact on the development of the services market
P - political	P1	public policy	changes in public policy can affect HEI funding, for example, research grants
	P2	regulatory changes	new laws and regulations may require additional resources to ensure compliance with standards
	P3	international relations	relations with other countries can affect opportunities for international cooperation and student exchange
E - economic factors	E1	economic climate	economic crises can negatively impact investment in and funding for higher education
	E2	energy costs	rising energy prices may reduce funding available for other initiatives
	E3	energy costs	rising energy prices may reduce funding available for other initiatives
S- social	S1	demographic changes	changes in the demographic composition of the population can affect the demand for higher education
	S2	cultural trends and value system	Cultural changes can affect educational programs and teaching methods
	S3	social changes	changes in society can affect the structure of the student body and educational programs
T - technological	T1	technological factors	the development of new technologies can change teaching methods and management of higher education institutions
	T2	digital technologies	the use of digital technologies can increase the efficiency of teaching and research
	T3	information systems	Information systems can improve HEI management

Source: developed by the authors

In order to assess the consistency and generalization of expert assessments, “the results of sample observation are analysed using statistical methods using data variation indicators, frequency or distribution centre indicators (Spearman rank correlation coefficients, Kendall concordances, and a one-way analysis of variance) (Grinko, 2021).

To assess the consistency of experts' opinions, we will use the Kendall coefficient, which involves calculating the concordance coefficient according to the formula:

$$W = \frac{12 \times S}{m^2 \times (n^3 - n)} \qquad (4.1)$$

where n is the number of observations; m is the number of experts; S - is determined by the formula below:

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$$S = \sum_{i=1}^{n} (\sum_{j=1}^{m} x_{ij} - \frac{1}{2} \times m \times (n+1))^2 \qquad (4.2)$$

The consistency of experts' opinions is confirmed provided that the Kendall coefficient takes values within 0.7 ÷ 0.9, with values of the coefficient W ≥ 0.7, the consistency of experts is of a sufficiently high level. The assessment of the consistency of experts' opinions was carried out using the STATISTIKA program. According to the results of the calculations, the concordance coefficient is 0.72, which indicates the consistency of experts' opinions.

Based on expert assessments, we will build a cognitive map of the external environment of Ukrainian higher education institutions (Figure 4.1).

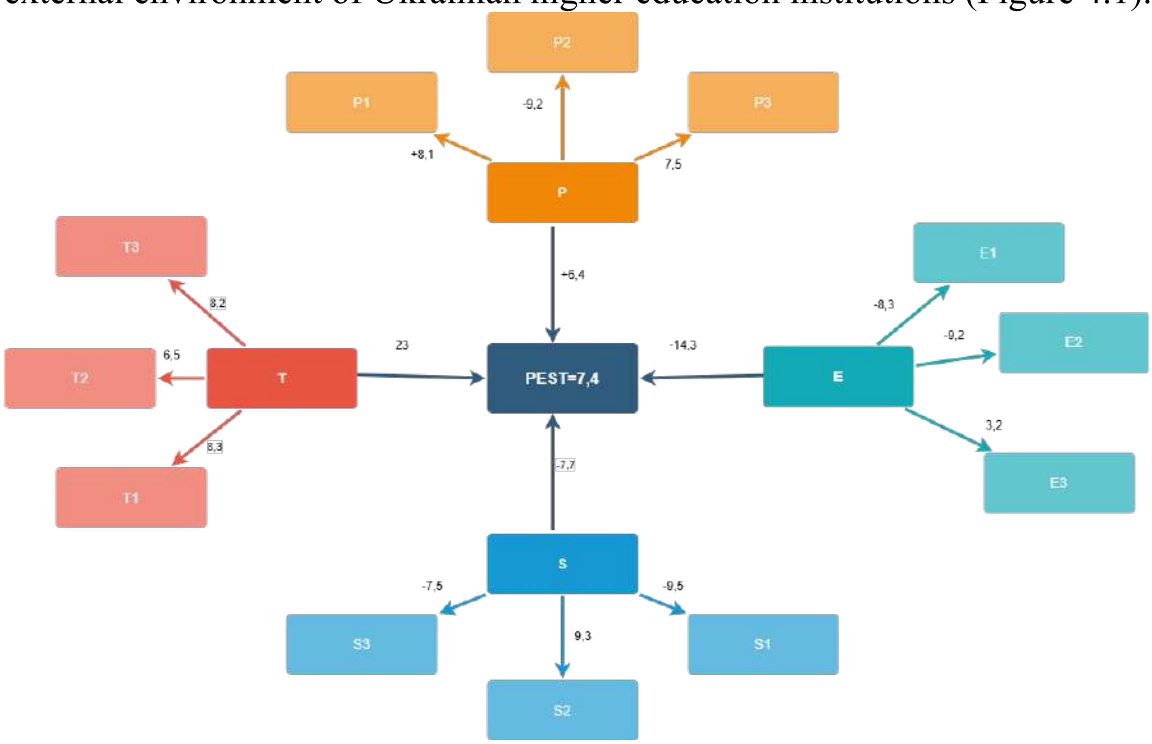

Figure 4.1. Cognitive map of PEST analysis of the external macroenvironment of Ukrainian HEIs

Source: developed by the authors

From Table 4.5 and Figure 4.1 we can draw conclusions about the predominantly negative impact of economic and social environmental factors

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on the processes of sustainable development of higher education institutions of Ukraine. The greatest negative impact among the factors of group "P" is exerted by political risk. A significant negative impact is exerted by regulation due to a significant number of regulatory changes. In fact, all factors of the political environment exert a negative impact on the development of higher education institutions, which is mainly due to the shortcomings of state regulation of the development of this sphere.

Assessment of the impact of the economic environment allows us to draw conclusions that the factors of group "E" have both a negative and positive impact on the processes of sustainable development of HEIs. The greatest impact on the processes of sustainable development of HEIs in Ukraine at the present stage is exerted by factors of tax changes and general economic trends. The structure and trends of GDP are an important indicator not only for the economic situation of the country as a whole, but also for specific HEIs. The inflation factor, which strongly affects the cost of resources, the cost of goods, works, and services, has the same assessment of the impact. In the process of assessing the impact of the external environment on the development of HEIs, appropriate assessments of the factors of the influence of the social environment on the development of the services market were obtained. In particular, it was established that the greatest impact on this process is exerted by such factors as the system of values in society, since entrants evaluate the quality of educational services and, in case of dissatisfaction, may refuse services. From the PEST analysis conducted, we can draw conclusions that in the group of factors of the technological environment, the factor of technology development has the greatest impact on the development of HEIs, which can change teaching methods and approaches to HEI management. Patent and license protection of technologies as a factor of the technological environment has a minor impact due to the existing influence only in certain sectors of the educational services market in Ukraine. A positive assessment of the external environment of 7.4 points on a 10-point scale, where 1 is the lowest score, 10 is the highest score, indicates the predominance of trends of positive total impact of macroenvironmental factors and indicates the possibility of increasing trends of sustainable development of Ukrainian HEIs.

2. Identifying the main opportunities and threats for HEIs. The next step is to conduct an empirical SWOT analysis of the Ukrainian higher education market environment and identify the main opportunities and threats for HEIs. It should be noted that the SWOT analysis of HEIs on the Ukrainian

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market is a useful tool for identifying their strengths and weaknesses, as well as opportunities and threats that arise in the context of modern challenges and changes. In particular:

1. Competitiveness assessment: SWOT analysis will identify the strengths of specific HEIs that provide them with competitive advantages in the higher education market (high quality of education, scientific achievements, international cooperation, or effective teaching methods).

2. Identification of weaknesses: through analysis, we will determine in which aspects the HEI has weaknesses, for example, limited infrastructure, lack of necessary resources, or insufficient level of teaching.

3. Identifying opportunities for development: A SWOT analysis will allow you to see new opportunities for development that may arise due to changes in the labour market, demand for certain professions, the development of digital technologies or international educational trends. This allows you to adapt strategies and accordingly increase the attractiveness of the institution for applicants.

4. Threat forecasting: threat analysis will allow you to identify external factors that may negatively affect the activities of a higher education institution, for example, changes in legislation, economic instability, competition from foreign educational institutions, a decrease in the number of applicants, or a reduction in funding.

5. Planning a development strategy: based on the results of the SWOT analysis, effective strategies for the development of higher education institutions can be developed, in particular, regarding improving the quality of education, optimizing finances, implementing new programs, and improving the image in the market.

6. Improving management efficiency: SWOT analysis helps HEI leaders make more informed decisions, which helps increase the efficiency of their work, ensure sustainable development, and improve their reputation in the market.

We used a unified system of criteria for assessing the strengths and weaknesses, opportunities and threats of HEIs in order to obtain comparative results. The universities selected for analysis were one state public university, which has the status of "national", and one private university, which has the status of "private".

The analysis used the scoring method (Kostynets & Kostynets, 2016) to evaluate all the specified criteria. The assessment was conducted by 11 experts

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from the higher education sector of Ukraine on a 5-point scale, where:

5 points - the most significant force of the factor;
4 points - significant force of the factor;
3 points - significant impact of the factor;
2 points - moderate strength of the factor;
1 point - insignificant force of the factor.

The sum of the points determines the overall assessment of the strength of each group of factors. To ensure the relevance of the assessment results, the same assessment criteria were used for each category of Ukrainian HEIs (Table 4.6).

Table 4.6. HEI evaluation criteria

Criterion	Explanation
Opportunities	
Development of digital technologies	the possibility of implementing online courses and distance learning
International cooperation	participation in international educational programs, exchange of students and scientific and pedagogical staff
Demand for specialized programs	growing demand for educational programs in the fields of IT, business, ecology, and medicine
Growing funding for education from international funds	the possibility of receiving grants for infrastructure development and scientific research
Development of startups and innovations	support for student and teaching startups and innovative projects
Increasing demand for educational services	growing demand for education among the adult population, reorientation towards " lifelong" learning » (lifelong learning)
Opportunities for integration into the European Education Area	adaptation to European education standards to attract international students
Tourism and cultural programs for students	development of cultural exchanges, participation in international conferences, festivals and scientific congresses
Threats	
Economic instability	reduction in funding from the state budget
Reducing the number of applicants	demographic decline, a decrease in the number of young people wishing to pursue higher education in Ukraine
High competition	increasing the number of educational institutions offering specialized programs
Student migration abroad	flow of students to foreign universities due to war and better prospects
Outdated infrastructure	lack of necessary funding for the modernization of the material and technical base of universities
Changes in legislation	frequent reforms in higher education, which can have unpredictable consequences for universities
Low adaptation of educational programs to employer requirements	insufficient orientation of training programs to the real needs of the labour market

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Criterion	Explanation
Low salaries for teachers	insufficient motivation for highly qualified personnel due to low salaries and unsatisfactory working conditions
Strengths	
Traditions and reputation	many universities have a long history and a strong image in Ukraine and abroad
Qualified teachers	availability of highly qualified teachers and scientists
Scientific potential	numerous scientific research, publications, developments
International exchange programs	participation in international academic programs and student and faculty exchange
Flexibility of curricula	the ability to adapt courses to the needs of students and the labour market
Access to state and international grants	the opportunity to receive funding for scientific research
Active student activities	the presence of modern libraries, laboratories, the presence of organizations and clubs that support cultural, sports, scientific and volunteer activities
Weaknesses	
Low teacher salaries	insufficient financial motivation for scientists and teachers
Insufficient funding	limited budget, which negatively affects the development of universities
Outdated educational content	inconsistency of some programs with modern labor market requirements and technological changes
Bureaucracy and delays in decision-making	complexity in the procedure for making management decisions due to excessive bureaucracy
Low mobility of students and teachers	limited opportunities for internships and academic exchanges abroad
Problems with graduate employment	lack of effective graduate employment programs
Low level of use of modern technologies in education	insufficient introduction of new technologies into the educational process

Source: developed by the authors

According to the results of expert assessments, the total result of the assessment of the capabilities of Ukrainian HEIs was estimated at 35.1 points. The greatest impact on the development capabilities of HEIs is caused by international cooperation, increased funding for education from international funds, the level of development of digital technologies, opportunities for integration into the European educational space, and increased demand for educational services.

The greatest threats to the development of Ukrainian HEIs are caused by the decrease in the number of entrants and their migration abroad under martial law, economic instability in the country, low adaptation of educational programs to the requirements of employers, low salaries of scientific and pedagogical employees, and outdated HEI infrastructure.

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When assessing the strengths and weaknesses of the state public university, experts noted the following advantages of the HEI: traditions and reputation, access to state and international grants, qualified scientific and pedagogical staff, and significant scientific potential of employees. Among the weaknesses are the low level of use of modern technologies in the educational process, insufficient funding, and problems with graduate employment.

The SWOT analysis map of the state public university is presented in Table 4.7.

Table 4.7. SWOT analysis map of the state public university

Opportunities	Mark	Threats	Mark
1	2	3	4
- development of digital technologies	4.8	- economic instability	4.8
- international cooperation	4.9	- decrease in the number of applicants	4.9
- demand for specialized programs	3.7	- high competition	3.2
- growth in education funding from international funds	4.9	- student migration abroad	4.9
- development of startups and innovations	3.7	- outdated infrastructure	4.5
- increasing demand for educational services	4.5	- changes in legislation	3.6
- opportunities for integration into the European educational space	4.7	- low adaptation of educational programs to the requirements of employers	4.8
- tourism and cultural programs for students	3.7	- low salaries for teachers	4.7
Total points	35.1	Total points	35.5
Strengths	Mark	Weaknesses	Mark
- traditions and reputation	4.9	- low level of salaries of scientific and pedagogical workers	2.5
- qualified scientific and pedagogical workers	4.8	- insufficient funding	4.4
- scientific potential	4.5	- outdated educational content	3.1
		- bureaucracy and delays in decision-making	2.9
- international exchange programs	3.5	- low mobility of students and academic staff	3.6
- flexibility of educational programs	3.7	- problems with graduate employment	4.3
- access to state and international grants	4.8	- low level of use of modern technologies in education	4.5
- active student activities	4.7		
Total points	31.0	Total points	25.3

Source: developed by the authors

To determine the field of interaction of factors influencing the SWOT analysis matrix, where the optimal development strategies for a particular

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university or their categories are located, it is advisable to find out which combination of factors has the greatest impact on the development process of the university for which the SWOT analysis matrix is being built. For this purpose, we will use the methodology proposed by a number of scientists (Kostynets & Kostynets, 2016), within which the assessment of the strength of interaction of factors is calculated as the product of the sum of the scores of the corresponding factors according to the formulas (4.3 - 4.6):

$$X_{SO} = \sum X_S \times \sum X_O \qquad (4.3)$$

where X_{SO} is a cumulative score of the feasibility of implementing the strategy of combining strengths and opportunities; $\sum X_S$ - overall assessment of the strength of the strengths, determined by the sum of the points; $\sum X_O$ - overall assessment of the strength of the opportunities, determined by the sum of the points.

$$X_{ST} = \sum X_S \times \sum X_T \qquad (4.4)$$

where X_{ST} is a cumulative score of the feasibility of implementing the strategy of combining strengths and threats; $\sum X_T$ - overall assessment of the strength of threats, determined by the sum of points.

$$X_{WO} = \sum X_W \times \sum X_O \qquad (4.5)$$

where X_{WO} is a cumulative score assessment of the feasibility of implementing the strategy of combining weaknesses and opportunities; $\sum X_W$ - overall assessment of the strength of the weaknesses, determined by the sum of the points.

$$X_{WT} = \sum X_W \times \sum X_T \qquad (4.6)$$

where X_{WT} is a cumulative score of the feasibility of implementing a strategy of combining weaknesses and threats.

As a result of the interaction of factors in the SWOT matrix, the following areas are formed: SO - the area of interaction of strengths and opportunities; WO - the area of interaction of weaknesses and opportunities; ST - the area of interaction of strengths and threats; WT - the area of interaction of weaknesses and threats. In accordance with the pair interactions that are in these areas, a further economic business model is built for each specific HEI. According to the results of the calculations, we obtain a generalizing SWOT matrix for choosing the optimal strategy for the state public university (Table 4.8).

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Table 4.8. Summarizing SWOT matrix for state public university

		Opportunities	Threats
		$\sum X_O = 35.1$ points	$\sum X_T = 35.5$ points
Strengths	$\sum X_S = 31$ points	SO $X_{SO} = 35.1*31=1088.1$	ST $X_{ST} = 31*35.5=1100.5$
Weaknesses	$\sum X_W =$ 25.3 points	WO $X_{WO} = 25.3*35.1 =888.03$	WT $X_{WT} = 25.3*35.5=898.15$

Source: developed by the authors

According to the calculation results, the greatest value is reflected in the field of interaction of strengths and threats, where the cumulative score (which determines the area of the rectangle that characterizes the selected strategy in the SWOT analysis matrix) is 1100.5 points.

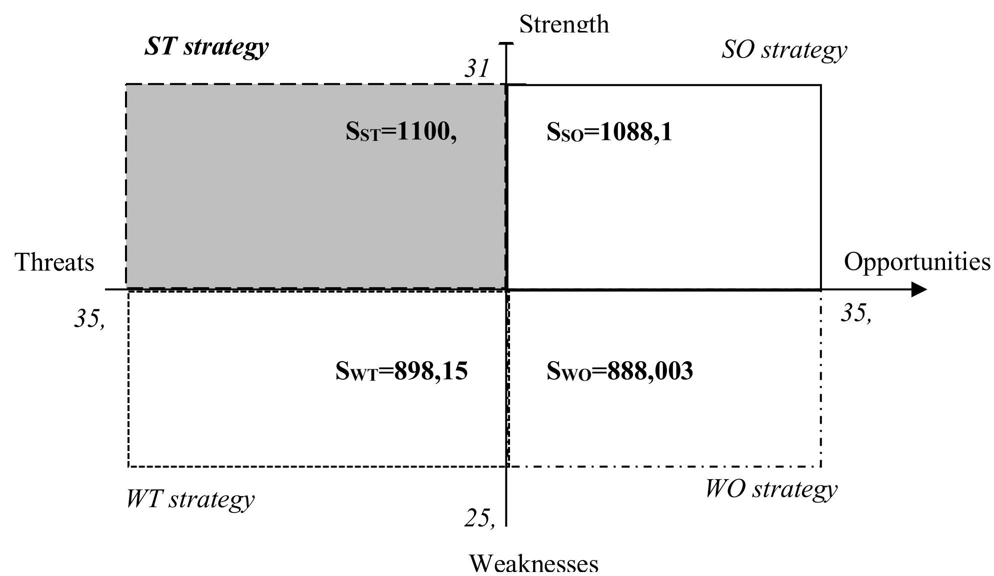

Figure 4.2. SWOT matrix of alternative sustainable development strategies of state public university

Source: developed by the authors

According to the results of expert assessments, it was found that an alternative strategy for the state public university is a strategy of horizontal diversification (the “strength-threat” quadrant) - the HEI has a high level of competitive potential and operates in an unstable external environment. The level of development of the HEI allows it to develop new specialties in

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accordance with market requirements and strengthen its positions in the international educational environment. In the face of external threats, the analysed state public university has the opportunity to maintain high ranking positions among HEIs of Ukraine, as well as to promote long-term sustainable development through increased marketing activity, resource optimization, expansion of social initiatives and better awareness of the target audience.

The next object of strategic analysis and evaluation is the Ukrainian higher education institution - private university. According to the results of expert assessments, the university's strengths include the flexibility of educational programs, active student activity, support for traditions and reputation, and proper qualification of scientific and pedagogical workers. The weaknesses are the low level of salaries of scientific and pedagogical workers, problems with graduate employment, low mobility of students and scientific and pedagogical workers, and insufficient funding. SWOT analysis map of the private university is presented in Table 4.9.

Table 4.9. SWOT analysis map of private university

Opportunities	Mark	Threats	Mark
- development of digital technologies	4.8	- economic instability	4.8
- international cooperation	4.9	- decrease in the number of applicants	4.9
- demand for specialized programs	3.7	- high competition	3.2
- growth in education funding from international funds	4.9	- student migration abroad	4.9
- development of startups and innovations	3.7	- outdated infrastructure	4.5
- increasing demand for educational services	4.5	- changes in legislation	3.6
- opportunities for integration into the European educational space	4.7	- low adaptation of educational programs to the requirements of employers	4.8
- tourism and cultural programs for students	3.7	- low salaries for teachers	4.7
Total points	**35.1**	**Total points**	**35.5**
Strengths	Mark	**Weaknesses**	Mark
- traditions and reputation	3.7	- low level of teachers' salaries	4.7
- qualified scientific and pedagogical workers	3.7	- insufficient funding	4.3
- scientific potential	3.4	- outdated educational content	3.3
- international exchange programs	3.4	- bureaucracy and delays in decision-making	2.6
- developed infrastructure in leading universities	4.7	- low mobility of students and academic staff	4.4
- flexibility of educational programs	2.7	- problems with graduate employment	4.5
- access to state and international grants	3.8	- low level of use of modern technologies in education	3.5
- active student activities	0.1		
Total points	**25.5**	**Total points**	**27.3**

Source: developed by the authors

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Based on the results of the calculations, we obtain a general SWOT matrix for choosing the optimal strategy for Ukrainian HEIs with the status of "private HEI". General SWOT matrix for HEIs of Ukraine with the status of "private HEI" is given in Table 4.10.

Table 4.10. Summarizing SWOT matrix for private university

		Opportunities	Threats
		$\sum X_O = 35.1$ points	$\sum X_T = 35.5$ points
Strengths	$\sum X_S = 25.5$ points	SO $X_{SO} = 35.1*25.5=895.05$	ST $X_{ST} = 25.5*35.5=905.25$
Weaknesses	$\sum X_W =$ 27.3 points	WO $X_{WO} = 35.1*27.3 =958.23$	WT $X_{WT} = 27.3*35.5=969.15$

Source: developed by the authors

According to the calculation results, the greatest importance for private higher education in Ukraine is reflected in the field of interaction of weaknesses and threats, where the cumulative score is 1178 points.

Therefore, for the private university it is worth using an anti-crisis strategy of sustainable development, since the results of the assessments showed that the weaknesses exceed the strengths. The HEI should conduct an internal audit to develop and implement measures to identify "bottlenecks" in management. Such a HEI should optimize its own costs, adapt educational programs to the needs of external stakeholders, conclude cooperation agreements with foreign universities in order to strengthen the scientific work of scientific and pedagogical workers and increase the opportunities for academic mobility of higher education applicants and scientific and pedagogical workers.

In general, it is worth noting that the outlined opportunities, threats, strengths and weaknesses of HEIs have a direct impact on the prospects for the sustainable development of higher education in Ukraine. For the sustainable development of HEIs, it is important that they adapt their strategies to changes in the global and local environment, thus contributing to the sustainable development of society and science.

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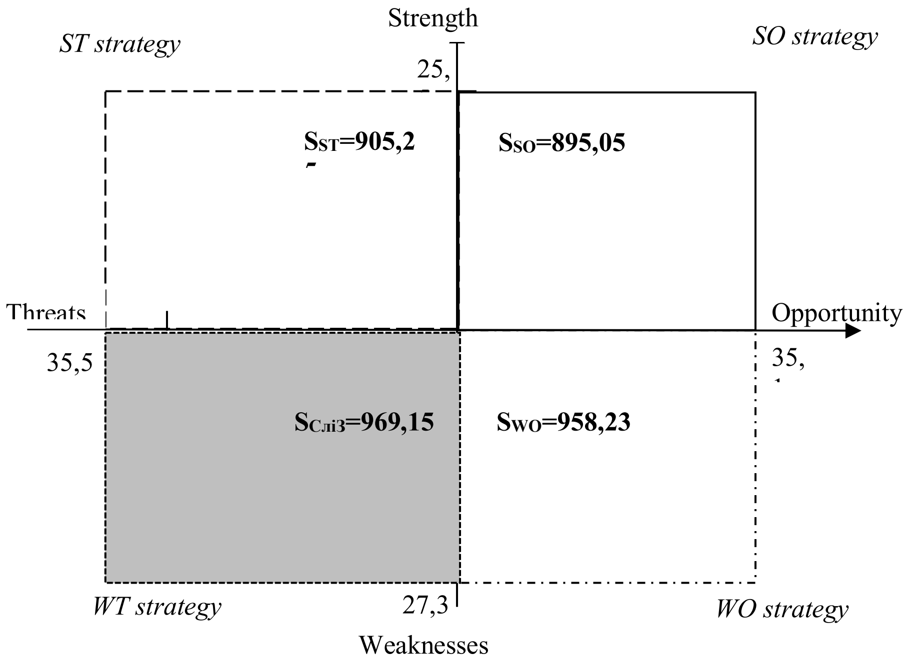

Figure 4.3. SWOT analysis matrix of alternative sustainable development strategies of the private university

Source: developed by the authors

Positive factors influencing the sustainable development of universities:

– opportunities for international cooperation and exchange - international exchange programs and cooperation with universities around the world open up new horizons for the development of science, education, and innovation. They allow students and teachers to have access to new knowledge and resources, which contributes to the quality of the educational process and scientific achievements;

– development of digital technologies - the introduction of digital technologies, in particular online courses, distance learning, the use of artificial intelligence and other innovative approaches, allows to increase the accessibility of education, reduce the costs of the educational process and ensure continuous learning, which is an important component of sustainable development;

– funding through international grants - attracting grants for infrastructure development, scientific research, and the introduction of innovative technologies is an important factor in supporting the sustainable development of universities, as it allows for the provision of additional resources that are

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not dependent on the limited state budget;

– demand for specialized programs - responding to the growing demand for new specialties (for example, in the field of technology, ecology, medicine) allows universities to remain relevant and adaptable to changes in the labour market, which contributes to the development of highly qualified personnel for the sustainable economic development of the country;

– active student activity - support for student initiatives, volunteer movements and other forms of social activity contributes to the development of civic consciousness, strengthening social ties and the formation of sustainable values among young people.

Negative factors influencing the sustainable development of universities:

– economic instability and declining funding - lack of funding is one of the main threats to the sustainable development of universities. Without an adequate budget, it is impossible to upgrade infrastructure, provide high-quality education, and attract talented teachers. This also limits opportunities for research and innovation;

– outdated infrastructure - if universities do not update their physical infrastructure (laboratories, classrooms, computer labs), this limits access to the latest technologies and knowledge needed for sustainable development. Insufficient investment in infrastructure can also affect the ability of universities to attract students and faculty;

– low salaries of teachers - low salaries can lead to qualified personnel leaving abroad or to a decrease in their motivation for scientific activity. This negatively affects the quality of education and the innovative potential of universities, which is an obstacle to their sustainable development;

– low adaptation to labour market requirements - if universities do not adapt their curricula to the needs of the labour market and technological changes, this leads to the graduation of students who do not have the necessary skills for effective work. This creates a gap between education and the real needs of the economy, which makes it difficult to ensure sustainable development of the national labour market;

– bureaucracy and administrative delays - excessive bureaucracy, slow administrative processes and inefficient decision-making can hinder rapid response to changes and challenges in education and science. This can lead to lost opportunities for development and a decrease in the competitiveness of universities;

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– migration of students and academic staff abroad - the movement of students and teachers to more developed countries is a serious threat to universities in Ukraine for a number of reasons, as it limits their potential and opportunities for the development of national education.

The areas of support for the sustainable development of Ukrainian universities, in turn, are:

– adaptation of curricula to changes in the labour market and new technologies;

– modernization of infrastructure through attracting additional resources, including international grants and partnerships;

– improving teacher motivation through increasing salaries and creating conditions for professional development;

– developing partnerships with international universities and organizations to attract resources and exchange experiences;

– introduction of innovative teaching methods and active use of the latest technologies to improve the educational process;

Balancing opportunities and threats, as well as eliminating weaknesses and using strengths, will help Ukrainian universities achieve sustainable development in the face of modern challenges.

Conclusions. In conclusion, it should be noted that the conducted strategic analysis demonstrated that for the sustainable development of Ukrainian universities it is important to use opportunities such as international cooperation, the development of digital technologies and specialized programs. However, there are also threats such as economic instability and reduced funding, which can complicate this process. Strengths such as qualified scientific and pedagogical staff and scientific potential help universities maintain competitiveness, but outdated infrastructure and low salaries of scientific and pedagogical staff remain serious problems. For sustainable development, it is necessary to adapt educational programs, modernize infrastructure and create conditions for the development of scientific and pedagogical staff and students, as well as respond to changes in the labour market.

Based on the results of a comprehensive strategic analysis sustainable development institutions higher education Ukraine is recommended to adapt one of the typical strategies sustainable development depending from combinations internal resources and external conditions.

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Strategy integration growth (the “strengths - opportunities” quadrant) is a priority for HEIs with high level internal potential and positive influence external environment. It involves long -term orientation growth through diversification educational services, implementation innovative programs, active international cooperation, as well as strengthening reputational and social capital. Key elements strategy is a combination vertical integration (cooperation with educational institutions lower level, local authorities self-government, social partners) and horizontal integration (merger with other HEIs, joint projects with business and the public sector). This gives opportunity create steel educational and scientific ecosystems, to increase financial stability, ensure access to new markets and educational niche. Special emphasis is placed on environmental consciousness, digital transformation, provision equal access to education, support socially vulnerable categories population, inclusiveness educational process and promotion cultures social responsibility through educational and scientific programs. Participation in national and international initiatives sustainable development, in particular in the implementation Goals sustainable The UN Development Goals (SDGs) are a mandatory component of the strategy.

Strategy horizontal diversification (the “strength- threat” quadrant) is focused on HEIs with highly competitive potential, which operate in a complex or unstable external environment. Within this one strategy achieved increase institutional flexibility and adaptability by expansion educational proposals, implementation new educational formats (mass open online courses, dual education, modular short-term programs), digitalization educational environments and transformations organizational culture. Strategy takes into account modern social, environmental and ethical challenges, including training needs personnel for the "green" economy, promoting gender equality, bridging the digital divide and social isolation. Through the development international partnership, participation in global educational networks and implementation international projects, HEIs provides mobility, internationalization and active promotion own contribution to the achievement global priorities sustainable development. Horizontal diversification also allows to implement strategies corporate social responsibility, in particular through volunteering programs, social oriented initiatives, educational environmental campaigns cultures etc.

Strategy vertical integration (the “weakness - opportunity” quadrant) is suitable for HEIs with limited internal potential, but under the conditions

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favourable external environment. The main goal is to strengthen institutional capacity building through the creation of stable partnerships, multi-level integration into educational, scientific, business and municipal space. Such a strategy gives opportunity create educational clusters and provide continuity educational process - from general medium to high education taking into account the needs of regional markets labour, inclusive development, social cohesion and environmental responsibility. Vertical integration accompanied internal transformation: modernization educational programs taking into account principles stability, increase personnel qualifications, development digital infrastructure, implementation principles environmental management and transparent governance. Such actions contribute formation innovation space of higher education institutions, which corresponds to the principles of the " triad" sustainable development” - economic efficiency, social justice and environmental balance.

Anti-crisis strategy (quadrant "weaknesses - threats") is a response to crisis situations conditions functioning of HEIs - low internal potential, reduction demand for educational services, reduction financing, reduction trust from stakeholders. However, even in such conditions possible implementation elements sustainable development as a tool stabilization. Strategy provides optimization internal resources, reduction ineffective directions, restructuring managerial systems, amplification transparency, improvement mechanisms internal control, greening infrastructure and creating conditions for digital transition. Significant warning is given development social partnership, involvement public initiatives, local businesses and international donors to support functioning of the Higher Education Institutions. Anti-crisis strategy provides support socially vulnerable groups students, development psychosocial support, inclusive access to educational resources and formation cultures resilience. In the case of effective implementation this strategy can become the basis for the transition to more active models growth - horizontal diversification.

Suggested strategies aimed not only at increasing efficiency management and competitiveness of HEIs, but also on the integration social, environmental and institutional components that respond modern understanding concepts sustainable development as balanced development in three dimensions: economic, social and environmental.

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Section 4.3. EU Best Practices on Digital Transformation, AI and Inclusion in Universities

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Abstract. *EU universities increasingly frame digital transformation as a system-wide reform that reshapes governance, teaching and learning, research infrastructures, and student services, while explicitly linking modernization to inclusion and accountability. This study aims to synthesise EU best practices on digital transformation, responsible AI, and inclusion in ways that can be operationalised within university strategies and control systems. Methodologically, it applies a structured synthesis of EU policy instruments, regulatory acts, and implementation guidance, complemented by Eurostat indicators on digital skills, AI diffusion, and disability-related digital participation. The analysis identifies five recurring practice clusters. First, governance is strengthened through explicit operating models that differentiate strategic steering, portfolio delivery, data and interoperability governance, and assurance functions covering cybersecurity, educational quality, and AI risk. Second, interoperability is treated as a public value by implementing mobility and credential services as trusted digital public services, supported by Erasmus Without Paper, the European Student Card, and European Digital Credentials for Learning. Third, capacity building addresses uneven readiness, as only 56% of EU residents aged 16 to 74 had basic digital skills in 2023, prompting universities to scale competence frameworks, educator development, and micro-credentials. Fourth, responsible AI adoption relies on risk-based governance and assessment redesign in response to diffusion patterns, including 20% of enterprises using AI and 32.7% of people using generative AI in 2025. Fifth, inclusion by design is pursued through accessibility controls that respond to persistent gaps, such as 87.2% internet use among people with disability compared with 95.2% without in 2024. Overall, EU best practice integrates innovation with trust by making interoperability, integrity, and accessibility measurable outcomes. Further research should estimate causal effects on equity, learning quality, and administrative burden through longitudinal, mixed-method, and comparative cross-country designs.*

Keywords: *digital transformation; university governance; interoperability; European Education Area; micro-credentials; DigComp; DigCompEdu; AI governance; academic integrity; accessibility; inclusion by design; Digital Decade.*

1. Strategy and governance: institutional alignment with EU priorities and measurable objectives. Across the European Union, digital transformation in universities is increasingly framed as a systemic reform that reshapes governance, teaching and learning, research infrastructures, student services, and cross-border cooperation. This approach is anchored in EU policy packages that position universities as core actors of the "twin transition" and emphasise competitiveness, openness, and social cohesion (European Commission, 2022). At the same time, the EU explicitly links digitalisation with inclusion, warning that unequal access to devices, connectivity, and institutional capacity can reproduce structural disadvantages if digital transition is pursued as a purely technological upgrade (European Commission, 2020). A further driver is the EU-wide monitoring and target-setting logic of the Digital Decade, which translates transformation into measurable indicators for skills, infrastructures, and uptake of advanced technologies (European Parliament and Council of the European Union, 2022). Within this framework, best practices in European universities converge on four governance principles: strategic alignment with EU instruments, interoperability by design, responsible and lawful AI adoption, and inclusion as a measurable performance outcome rather than a declarative value.

EU best practices treat digital transformation in universities as a governance reform that reconfigures how institutions plan, decide, allocate resources, and assure quality across teaching, research, and services. This approach is consistent with the European Strategy for Universities, which frames universities as key actors of European-scale cooperation and capacity building, and therefore implicitly requires stable institutional steering, interoperability-ready processes, and shared implementation capabilities across alliances (European Commission, 2022). In parallel, the Digital Education Action Plan 2021 to 2027 reinforces that digital education must be high-quality, inclusive, and accessible, which means that governance must address equity, staff readiness, and infrastructure constraints as first-order strategic issues rather than operational afterthoughts (European Commission, 2020; European Commission, 2025). The Digital Decade Policy Programme further strengthens this logic by embedding digital transformation into a target-based EU framework, including an explicit target that at least 80% of those aged 16 to 74 should have at least basic digital skills by 2030, which encourages institutions to connect their strategies to measurable indicators and

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public accountability (European Parliament and Council of the European Union, 2022).

A deeper governance implication is that universities increasingly require an institutional “operating model” for digital transformation that clarifies roles, decision rights, and accountability across academic and administrative domains. In mature EU practice, this operating model includes a steering layer that legitimises priorities (for example, a rectorate-level committee), an execution layer that manages delivery (for example, a digital transformation office), and an assurance layer that monitors compliance, data protection, cybersecurity, and educational quality. This structure aligns with EU policy expectations that digitalisation should strengthen resilience and quality, not merely expand technology uptake (European Commission, 2020; European Commission, 2022).

Universities also treat digital transformation as a portfolio, not a single project, because outcomes depend on coordinated changes in curriculum, pedagogy, infrastructure, student services, and staff competencies. In this model, portfolio governance becomes a mechanism for preventing fragmentation, controlling duplication, and ensuring that investments support institutional mission and inclusion goals that EU documents foreground (European Commission, 2020; European Commission, 2022).

A second best practice is to link governance explicitly to measurable objectives, because EU policy frames digital transition through targets and monitoring, and universities are increasingly assessed through performance-oriented public funding and quality assurance regimes. The Digital Decade targets provide a useful reference architecture for institutional KPIs, especially in domains of skills, digital infrastructure readiness, and technology uptake, even if universities must tailor measurement to their context (European Parliament and Council of the European Union, 2022).

Practically, this produces a governance approach where each major initiative is associated with indicators and thresholds, for example staff training completion rates, accessibility compliance levels, process digitalisation coverage, and student experience metrics. Importantly, inclusion must be built into measurement itself, because the Digital Education Action Plan explicitly frames inclusiveness and accessibility as core objectives, so a “digital success” indicator that ignores distributional effects is inconsistent with EU best practice (European Commission, 2020; European Commission, 2025). This is also where governance must integrate risk

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management, since rapid digitalisation and AI adoption can create harms if decision systems are opaque, biased, or insufficiently overseen.

A third best practice is to incorporate AI governance early as part of the institutional strategy, rather than treating AI as a purely pedagogical or technical choice. The EU Artificial Intelligence Act establishes a risk-based regulatory approach and harmonised rules, reinforcing the expectation that organisations deploying AI in sensitive contexts should apply governance controls that ensure accountability, transparency, and appropriate oversight (European Parliament and Council of the European Union, 2024).

For universities, the governance challenge is not only compliance, but also legitimacy, since AI tools can affect assessment validity, student trust, and the fairness of learning pathways. Consequently, EU-aligned governance tends to define acceptable use cases, approval pathways for high-impact applications, documentation requirements, and human oversight responsibilities for AI-enabled processes in teaching, student services, and administration (European Parliament and Council of the European Union, 2024).

The operating model becomes implementable when universities formalise governance layers and decision rights so that strategy, delivery, and assurance remain aligned with EU priorities (Table 4.11)

Table 4.11. Governance operating model for EU-aligned university digital transformation

Governance layer	Core function	Typical roles and decision rights	EU alignment rationale
Strategic steering	Sets priorities and allocates resources	Rectorate-level committee; approval of portfolio, funding, and institutional targets	Connects institutional strategy to EU objectives on cooperation, quality, and inclusion (European Commission, 2022; European Commission, 2020).
Portfolio management and delivery	Executes programmes and manages dependencies	Digital transformation office; project owners across faculties and services; change management function	Reduces fragmentation and supports capacity building emphasised in EU education policy (European Commission, 2025).
Data and interoperability governance	Ensures standardisation, data quality, and cross-system integration	Data governance board; enterprise architecture; standards for identity, credentials, mobility workflows	Supports European-scale cooperation and interoperability needs implied by EU university strategy (European Commission, 2022).
Risk, compliance, and quality assurance	Controls risk and safeguards trust	Information security, legal and ethics, QA unit; AI risk register; audit and review cycles	Reflects risk-based governance expectations for AI and promotes trustworthy digital education (European Parliament and Council of the European Union, 2024; European Commission, 2020).

Sources: developed by author based on (European Commission, 2022; European Commission, 2020)

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EU best practice is strongest where governance is explicit about decision rights and assurance mechanisms, because this reduces ad hoc implementation and supports a stable institutional transition consistent with EU strategy and digital education principles (European Commission, 2022; European Commission, 2020).

A fourth best practice is to translate EU priorities into an institutional measurement system that balances performance, inclusion, and integrity. The Digital Decade provides a clear example of how targets can be used to coordinate action, and universities can adapt this logic by defining indicators that show both overall progress and distribution across student groups (European Parliament and Council of the European Union, 2022).

The Digital Education Action Plan further implies that quality and inclusion must be monitored in hybrid and digital education, which motivates indicators on accessibility of materials, staff readiness, and student support responsiveness (European Commission, 2020; European Commission, 2025).

When AI is introduced, governance benefits from metrics that monitor not only usage but also impacts, such as assessment integrity incidents, transparency compliance, and the number of AI-enabled processes subject to documented oversight (European Parliament and Council of the European Union, 2024).

The strongest models treat these indicators as decision inputs for budgeting and programme prioritisation, so measurement is not a reporting exercise but a control mechanism that shapes action.

To make EU alignment operational, universities typically map EU policy objectives to institutional KPIs that can be reviewed quarterly or annually and used in portfolio decisions (Table 4.12).

KPI mapping is a core EU-aligned practice because it connects policy-level objectives to managerial control, enabling universities to steer transformation through evidence-based prioritisation rather than technology-driven opportunism (European Parliament and Council of the European Union, 2022; European Commission, 2020).

A deeper reading of EU best practices shows that strategy and governance are the structural determinants of successful digital transformation in universities. EU frameworks emphasise European-scale cooperation, inclusive and accessible digital education, and target-based accountability, which collectively require universities to formalise operating models, portfolio governance, and measurable indicators (European Commission,

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2022; European Commission, 2020; European Parliament and Council of the European Union, 2022).

Table 4.12. Example KPI mapping for EU-aligned governance in universities

EU objective reference	Institutional KPI domain	Example indicators (illustrative)	Governance use
Inclusive and accessible digital education (Digital Education Action Plan)	Teaching quality and inclusion	Share of courses meeting accessibility and inclusive design criteria; staff completion of digital pedagogy training; student satisfaction by subgroup	Prioritises investments in learning design, support services, and staff development (European Commission, 2020; European Commission, 2025).
Digitally skilled population, including 80% basic digital skills target (Digital Decade)	Student skills outcomes	Digital competence attainment rates across programmes; bridging course completion for underprepared cohorts	Links curriculum reform to measurable outcomes aligned with EU targets (European Parliament and Council of the European Union, 2022).
European-scale university cooperation (European Strategy for Universities)	Inter-institutional readiness	Number of alliance-shared digital services; time to process cross-border student workflows; uptake of interoperable processes	Supports cooperation and alliance implementation capacity (European Commission, 2022).
Risk-based AI governance (AI Act)	AI accountability and integrity	Share of AI use cases registered and risk-assessed; transparency and documentation compliance; integrity incidents and response time	Embeds lawful and responsible AI adoption into institutional control systems (European Parliament and Council of the European Union, 2024).

Sources: developed by author based on (European Parliament and Council of the European Union, 2022; European Commission, 2020)

The integration of AI governance into strategy strengthens institutional trust and reduces the risk that AI adoption undermines integrity or fairness, aligning with the risk-based approach embedded in EU AI regulation (European Parliament and Council of the European Union, 2024). Overall, EU-aligned governance performs a dual role: it accelerates innovation by reducing fragmentation, and it protects inclusion and legitimacy by embedding quality and accountability into the transformation process.

2. Interoperability and digital public services: mobility, credentials, and cross-border trust infrastructures. EU best practices conceptualise interoperability in universities as a public value and a functional necessity for the European Education Area, rather than as a purely technical preference. The European Strategy for Universities links the ambition of European-scale cooperation to the practical capability of institutions to operate joint activities, streamline mobility, and reduce administrative barriers, all of which presuppose interoperable digital processes and shared standards across borders (European Commission, 2022). In this perspective, mobility is treated as a lifecycle of services, from nomination and application to learning agreement, recognition, and credential issuance, where each step generates data that must be exchanged securely and consistently. The European Student Card Initiative (ESCI) embodies this logic by aiming to simplify administrative processes and enhance digitalisation for Erasmus+ exchanges (European Commission, 2025). Crucially, the ESCI architecture relies on the ESC Router, which enables participating institutions to integrate ESC features into student cards and supports real-time validation of student status across the European Education Area (European Commission, 2025).

The governance implication is that "mobility readiness" becomes a university-wide capability, requiring coordinated ownership across registrar functions, international offices, IT services, and quality assurance, because a failure in interoperability at any node creates delays, duplications, and inequitable burdens for students and staff.

A central operational pillar of EU interoperability practice is Erasmus Without Paper (EWP), which connects higher education institutions' mobility management systems so that mobility can be managed online (European Commission, 2025). The design principle highlighted in EU guidance is that institutions keep their existing mobility system and connect it to the EWP network, which reduces the need for disruptive replacement projects while enabling standardised exchange of mobility documents and data (European Commission, 2022). In other words, interoperability is achieved through networked integration, not through enforced uniformity of software. This approach is consistent with a public-service model in which universities are autonomous but must still coordinate through common technical and procedural rules to make mobility scalable and inclusive. EU onboarding guidance further frames EWP as a progressive transition, where institutions with an Erasmus Charter for Higher Education commit to gradually adopting the network for Erasmus+ administrative tasks (European Commission, 2024). The best-practice implication is that universities need a staged implementation plan, coupled with change management and staff training,

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because mobility processes involve high volumes of routine decisions and time-critical coordination that cannot depend on informal workarounds.

A deeper understanding of interoperability emerges when mobility is mapped as a service lifecycle, because each stage implies specific data exchanges, verification needs, and integrity controls (Table 4.13).

Table 4.13. Mobility lifecycle as an interoperable digital public service in EU universities

Mobility stage	Typical administrative artefacts	Interoperability mechanism in EU practice	Key governance requirement
Pre-mobility identification and eligibility	Student status confirmation; institutional identifiers	ESC features integrated via the ESC Router enable real-time status validation (European Commission, 2025).	Data governance for identifiers and authoritative sources of truth
Learning agreement and approvals	Learning agreement, approvals, course catalogue references	EWP supports digital exchange rather than paper or PDF workflows (European Commission, 2022; European Commission, 2025).	Process standardisation across faculties, with clear decision rights
Mobility administration during exchange	Amendments; confirmations; institutional messaging	Connected mobility systems through EWP networked integration (European Commission, 2025).	Operational continuity, service-level responsibility, staff support
Recognition and transcript exchange	Transcript of records; recognition decisions	EWP-enabled exchange and standardised data transfer reduce manual re-entry (European Commission, 2022).	Quality assurance for recognition, audit trails for decisions
Credential issuance and verification	Diploma; micro-credential; certificate	European Digital Credentials for Learning enable issuing and verification in digital format (European Commission, 2025).	Integrity controls, formal signing and verification procedures

Sources: developed by author based on (European Commission, 2025; European Commission, 2024)

Treating mobility as an interoperable service lifecycle clarifies why EU best practice requires both technical integration and institutional governance, because verification, recognition, and credential integrity depend on consistent rules across units and partner institutions (European Commission, 2025; European Commission, 2024).

Interoperability also extends beyond mobility to the long-term portability of learning outcomes, where EU best practices prioritise verifiable digital credentials. European Digital Credentials for Learning (EDC) are framed by the European Commission as a verifiable digital version of a credential that

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can cover diplomas, transcripts, micro-credentials, and certificates of participation (European Commission, 2025). The Commission also indicates that it provides an infrastructure to create, issue, view, store, share, and verify such credentials, which shifts credentialing from a paper-based, institution-bound process to an ecosystem model with standardised verification (European Commission, 2025). A particularly important best-practice feature is that EDC can be signed with an electronic seal, linking educational credentials to trust services and strengthening tamper-resistance and authenticity checks (European Commission, 2025). For universities, the governance challenge is not only issuing credentials but also ensuring that credential data structures are consistent, that issuance is tied to quality assurance decisions, and that verification remains possible across borders and over time. This encourages institutions to formalise credential governance, including template management, metadata quality controls, and clear responsibility for institutional seals and verification endpoints.

A deeper layer of EU best practice is the construction of cross-border trust infrastructures that make interoperability reliable in high-stakes contexts. The revised eIDAS framework, via Regulation (EU) 2024/1183, strengthens the European digital identity architecture and supports the establishment of European Digital Identity Wallets, reinforcing cross-border recognition and trust in electronic identification and credentials (European Parliament and Council of the European Union, 2024). European Commission materials on the European Digital Identity Wallet present it as a safe and reliable means of digital identification to be provided by Member States to citizens, residents, and businesses (European Commission, 2025). In the university setting, this trust layer matters because identity, authentication, and attribute verification underpin student status checks, mobility processes, and credential issuance. Best practices therefore increasingly treat identity and credentialing as part of enterprise architecture, where interoperability depends on stable trust services, consistent authentication methods, and well-defined data minimisation policies. This is also where inclusion intersects with interoperability, because digital identity, credential access, and mobile-first services must be usable for diverse groups, including those with accessibility needs, or else digitalisation can become a barrier rather than an enabler.

Interoperability becomes more actionable when it is described as a layered trust stack, moving from identity to verified attributes to credentials, each with associated standards and governance controls (Table 4.14).

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Table 4.14. Trust and interoperability stack for EU university mobility and credential services

Layer	What is being trusted	EU mechanism or reference	Institutional best-practice control
Identity and authentication	Who the student or staff member is	European Digital Identity Wallet direction within EU digital identity framework (European Commission, 2025).	Strong authentication, role-based access, and privacy-preserving identity design
Verified attributes	Student status, enrolment, eligibility	ESC Router enables real-time status validation across the European Education Area (European Commission, 2025).	Authoritative data sources, clear attribute definitions, and governance for updates
Mobility data exchange	Mobility documents and structured data	EWP connects institutional systems to exchange mobility data digitally (European Commission, 2022; European Commission, 2024).	Standardised processes, audit trails, service continuity, and staff training
Credential integrity	Authentic diplomas and micro-credentials	EDC infrastructure supports issuance and verification, credentials signed with electronic seal (European Commission, 2025).	Credential templates, seal governance, and verification workflows integrated into QA

Sources: developed by author based on (European Commission, 2025; European Parliament and Council of the European Union, 2024)

EU best practice is stronger when universities treat interoperability as a trust stack, because mobility and credential services fail when identity, attribute verification, or credential integrity are weak or inconsistently governed (European Commission, 2025; European Parliament and Council of the European Union, 2024).

From an implementation standpoint, leading EU universities adopt a "connect and standardise" strategy that prioritises integration with EU networks and the standardisation of core data objects, rather than attempting to digitise every process simultaneously. EWP's principle of connecting existing systems supports incremental transition, but it also makes enterprise architecture and data governance decisive, because heterogeneous systems can exchange data only when meanings and validation rules are harmonised (European Commission, 2022). Similarly, ESC Router-based status validation requires consistent definitions of student status and timely synchronisation of enrolment data across institutional sources, which implies ongoing governance, not a one-time integration project (European Commission, 2025). For EDC, universities must align issuance with quality assurance decisions, ensure that micro-credentials and course achievements have consistent

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learning outcomes metadata, and establish a sustainable verification practice that remains valid for employers and partner institutions across borders (European Commission, 2025). These requirements show why EU best practice increasingly combines technical deployment with institutional policy instruments, including data stewardship roles, lifecycle management of credentials, and formal change control for mobility data standards.

A deeper reading of EU best practices shows that interoperability is a governance capability that operationalises European-scale cooperation through trusted, standards-based digital public services. The European Student Card Initiative and EWP illustrate how mobility can shift from document-driven administration to networked data exchange, reducing friction while increasing the need for clear decision rights, data governance, and service accountability (European Commission, 2025; European Commission, 2024). The European Digital Credentials for Learning extend this logic into credential portability, using verifiable credentials and electronic seals to strengthen integrity and cross-border recognition (European Commission, 2025). Finally, the EU trust infrastructure direction, reinforced by eIDAS reform and the European Digital Identity Wallet vision, indicates that identity and trust services are increasingly treated as foundational prerequisites for scalable, inclusive digital universities (European Parliament and Council of the European Union, 2024; European Commission, 2025).

3. Skills and capacity building: closing the readiness gap through EU targets, staff development, and micro-credentials (Expanded). EU best practices frame skills and capacity building as the binding constraint of university digital transformation, because technology adoption does not automatically translate into learning quality, organisational performance, or inclusion. This logic is formalised in the Digital Decade Policy Programme, which sets a measurable target that at least 80% of people aged 16 to 74 should have at least basic digital skills by 2030, alongside a target of at least 20 million ICT specialists employed in the EU and an explicit emphasis on gender balance (European Parliament and Council of the European Union, 2022). The current gap is substantial: Eurostat reported that only 56% of people in the EU aged 16 to 74 had at least basic overall digital skills in 2023, and subsequent Eurostat communication highlighted strong disparities by age and education, indicating that skills deficits are structurally patterned rather than randomly distributed (Eurostat, 2023; Eurostat, 2024).

In university terms, this means that cohorts enter higher education with

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unequal "readiness endowments", and institutions must provide compensatory pathways, not only advanced digital programmes for already prepared students. Best practice therefore treats capacity as a system: it covers student digital competence across disciplines, educator digital competence, leadership capability for governing transformation, and institutional infrastructure for sustained professional development and quality assurance (European Commission, 2025; European Commission Joint Research Centre, 2025).

A core EU-informed practice is to use competence frameworks as governance tools, not merely as pedagogical references. The Joint Research Centre's DigComp 2.2 provides a shared understanding of digital competence and includes extensive examples, including emerging technology domains such as AI-driven systems, which supports curriculum design and assessment alignment across programmes (Vuorikari et al., 2022). For educators, DigCompEdu offers a structured reference frame for educator-specific digital competences and supports coherent professional development planning in higher education, including the design of teaching practices, assessment strategies, and learner empowerment in digital environments (European Commission Joint Research Centre, 2025; Redecker, 2017). The governance implication is that universities can define baseline competence expectations for students and staff and then build progression pathways that are auditable, comparable, and compatible with European cooperation. This framework-based approach also strengthens inclusion, because it enables institutions to identify specific competence gaps and support needs rather than relying on general assumptions about "digital natives".

Capacity building in EU best practice also prioritises educators as the main transmission mechanism between institutional infrastructure and student outcomes. The Digital Education Action Plan policy background notes that fewer than 40% of educators across the EU felt ready to use digital technologies in teaching, referencing OECD evidence, which underlines that educator readiness is not an automatic by-product of student technology use (European Commission, 2025). In universities, this translates into a need for structured staff development that integrates pedagogical design, assessment literacy, and responsible use of data and AI. Best practice institutions typically create a professional development ecosystem with three layers: foundational training that ensures minimum capability for hybrid delivery, advanced pathways for discipline-specific digital pedagogy and learning analytics, and

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a mentoring or community-of-practice layer that stabilises adoption and reduces isolated, ad hoc experimentation. The underlying rationale is that sustainable quality requires routinised competence, shared standards, and support services, rather than sporadic training events.

A second structural constraint is the shortage and uneven composition of advanced digital professionals, which affects both university staffing and graduate pipeline capacity. Eurostat reported that women made up 19.5% of ICT specialists employed in the EU in 2024, illustrating that the advanced skills workforce remains strongly gender imbalanced and that inclusion objectives must be embedded in capacity strategies (Eurostat, 2025). EU best practices therefore combine skills expansion with inclusion measures that are specific and measurable, such as targeted recruitment into ICT and AI programmes, mentoring and retention interventions, and inclusive learning design that reduces attrition in technically demanding pathways. At institutional level, this also implies workforce planning for universities themselves, because without sufficient digital specialists and learning support staff, transformation initiatives tend to become vendor-dependent and unevenly implemented across faculties.

A readiness gap becomes governable when it is decomposed into dimensions that can be measured and managed through institutional responsibilities and indicators aligned with EU monitoring (Table 4.15).

EU-aligned universities close the readiness gap by managing it as a multi-dimensional capability, where student competence, educator competence, advanced talent, and support services are measured and governed as one system rather than treated as disconnected initiatives.

Micro-credentials constitute a third pillar of EU best practices because they offer a scalable mechanism for modular upskilling and reskilling that can serve students, staff, alumni, and regional labour markets. The Council Recommendation on a European approach to micro-credentials aims to improve clarity, trust, transparency, and uptake across Member States, and it encourages the use of common definitions and information requirements that make micro-credentials comparable and portable (Council of the European Union, 2022). For universities, the best-practice challenge is governance rather than production: micro-credentials must be designed with robust learning outcomes, assessment integrity, and quality assurance processes, and they must be integrated into credential ecosystems so that stickability toward degrees is credible.

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Table 4.15. University readiness dimensions aligned with EU skills priorities

Readiness dimension	What universities must build	Illustrative indicators for governance review	EU anchor reference
Student baseline digital competence	Minimum digital competence across disciplines, plus support for disadvantaged cohorts	Attainment of baseline competence by year 1; completion of bridging modules; subgroup gaps by age, socioeconomic proxies, disability status	80% basic skills target, and EU monitoring logic (European Parliament and Council of the European Union, 2022; Eurostat, 2023).
Educator digital competence	Capability to design, teach, and assess in digitally enhanced formats	Share of educators meeting DigCompEdu-aligned baseline; participation in advanced pathways; course quality reviews referencing digital pedagogy criteria	Educator readiness challenge highlighted in EU policy background (European Commission, 2025; Redecker, 2017).
Advanced digital talent pipeline	Graduates and researchers in ICT and AI, including inclusion outcomes	Growth of ICT and AI graduates; internships and placements; gender balance in programmes; retention rates	ICT specialists target and gender balance emphasis (European Parliament and Council of the European Union, 2022; Eurostat, 2025).
Institutional support capacity	Learning design support, data support, and scalable training services	Staffing of learning support units; service usage; time-to-support metrics; satisfaction and course improvement outcomes	Inclusive, high-quality digital education objective (European Commission, 2025).

Sources: developed by author based on (European Parliament and Council of the European Union, 2022; Eurostat, 2023)

When micro-credentials are aligned with competence frameworks such as DigComp 2.2 and issued through trustworthy digital credential infrastructures, they can reduce fragmentation and help universities respond to labor market demand for advanced digital skills without eroding academic standards (Vuorikari et al., 2022; Council of the European Union, 2022). EU-level initiatives in the advanced digital skills domain also point to the growing role of micro-credentials and certification frameworks in building European-scale skills capacity, reinforcing the need for universities to treat micro-credentials as strategic instruments rather than peripheral short courses (European Commission, 2025).

Because micro-credentials are meant to be trusted and portable, universities increasingly implement a design and quality checklist aligned with the Council Recommendation (Table 4.16).

https://doi.org/10.36690/CIDI-EME
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Table 4.16. Micro-credential design and quality checklist aligned with EU approach

Design element	What "EU-aligned" practice requires	Why it matters for digital transformation
Clear learning outcomes and workload transparency	Documented outcomes, workload, and level, with consistent terminology	Enables comparability and supports stackability and recognition (Council of the European Union, 2022).
Assessment integrity and evidence	Defined assessment method, criteria, and evidence of achievement	Protects trust and reduces risk of low-quality credential inflation
Quality assurance integration	QA process linked to institutional standards, programme boards, and periodic review	Prevents micro-credentials becoming an ungoverned parallel system
Stackability and pathway logic	Explicit rules for stacking toward degrees or professional pathways	Converts short learning into coherent lifelong learning routes
Inclusion and access design	Accessible delivery, targeted support, and monitoring of participation gaps	Aligns micro-credentials with inclusive digital education objectives (European Commission, 2025).

Sources: developed by author based on (Council of the European Union, 2022)

EU best practice treats micro-credentials as quality-assured components of a wider credential ecosystem, where transparency, assessment integrity, and pathway design are prerequisites for trust and scalability.

At implementation level, the most mature EU practices combine frameworks, staff development, and micro-credentials into an institutional capacity architecture. First, baseline competence expectations are defined for all students using a DigComp-informed model, with diagnostic entry assessment and targeted bridging modules for those who lack foundational skills (Vuorikari et al., 2022; Eurostat, 2024). Second, educator development is organised through DigCompEdu-aligned pathways and supported by learning design units, so that staff can redesign courses and assessment methods for hybrid environments and emerging AI-mediated learning practices (Redecker, 2017; European Commission Joint Research Centre, 2025). Third, micro-credentials are positioned as modular capacity instruments: they support staff upskilling, student specialisation, and regional engagement with SMEs and public sector partners, while maintaining trust through Council Recommendation-aligned transparency and QA (Council of the European Union, 2022). Across all three components, inclusion is operationalised through measurable targets and subgroup monitoring, especially in relation to gender in advanced digital skills and the distributional gaps implied by EU digital skills statistics (Eurostat, 2025; Eurostat, 2023).

EU best practices close the readiness gap by treating skills and capacity

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as a governed institutional system aligned with Digital Decade targets and EU digital education objectives (European Parliament and Council of the European Union, 2022; European Commission, 2025). The empirical gap in basic digital skills, together with disparities by age and education, implies that universities must provide structured compensatory pathways and not only advanced digital specialisations (Eurostat, 2023; Eurostat, 2024). Educator readiness remains a decisive bottleneck, so staff development should be DigCompEdu-aligned, quality-assured, and supported by dedicated learning design capacity (Redecker, 2017; European Commission Joint Research Centre, 2025). Micro-credentials add scalable modularity, but only when they are governed for transparency, integrity, and pathway logic as recommended at EU level (Council of the European Union, 2022). Finally, advanced digital capacity must be treated as an inclusion issue, given the persistent gender imbalance among ICT specialists, which requires targeted recruitment, retention, and progression interventions within universities (Eurostat, 2025).

4. Responsible AI adoption: risk-based governance, academic integrity, and institutional accountability. The accelerating diffusion of AI in the European economy and in everyday digital practices has transformed responsible AI adoption from an optional innovation agenda into a core university governance responsibility. Eurostat reports that in 2025, 20.0% of EU enterprises with 10 or more employees used AI technologies, representing a marked increase compared with 2024 and earlier years (Eurostat, 2025). At the same time, AI use is no longer confined to organisational settings, because Eurostat also indicates that 32.7% of people aged 16 to 74 in the EU used generative AI tools in 2025, including use for work (15.1%) and for formal education (9.4%) (Eurostat, 2025). For universities, these indicators imply that AI is shaping both graduate employability and the immediate learning environment, since students can bring powerful generative tools into coursework, assessment preparation, and research activities regardless of institutional policy. Consequently, EU best practice is increasingly defined not by whether universities permit AI, but by whether they can govern AI use coherently across teaching, research, and student services while protecting rights, academic standards, and trust.

A foundational element of EU-aligned best practice is the integration of risk-based AI governance into the university's operating model, in line with the regulatory logic of the EU Artificial Intelligence Act. The AI Act establishes harmonised rules for AI and is explicitly structured around risk,

https://doi.org/10.36690/CIDI-EME
ISBN 978-9916-9320-3-2 (pdf)

obligations, and accountability expectations, which encourages institutions to replace fragmented experimentation with documented governance and oversight (European Parliament and Council of the European Union, 2024).

In practical university settings, this means that AI governance should be organised around use cases, because the same tool can produce very different risks depending on context, for example low-risk writing support versus high-impact decision support in admissions, advising, or progression monitoring. A mature practice is therefore to maintain an institutional AI use-case register that classifies deployments by pedagogical and administrative purpose, data sensitivity, and potential rights impact, and then links each category to required controls such as transparency notices, human oversight, and escalation procedures (European Parliament and Council of the European Union, 2024). This risk-centred architecture is also consistent with the European University Association's position that universities should explore responsible use of AI tools in line with their missions and values, and with due regard to legal frameworks and broader societal consequences (European University Association, 2023).

Because responsible AI adoption depends on aligning concrete controls with concrete uses, an evidence-based mapping of AI diffusion into university governance requirements helps to justify why governance cannot remain informal.

Table 4.17. EU AI diffusion indicators and direct governance implications for universities

Indicator reported at EU level	Evidence	Why it matters for university governance
Share of EU enterprises (10+ employees) using AI in 2025	20.0% (Eurostat, 2025)	AI competence becomes a mainstream employability requirement, so universities must embed AI literacy and responsible use across curricula rather than limiting AI content to specialised programmes.
Share of EU people (16 to 74) using generative AI tools in 2025	32.7% overall; 15.1% for work; 9.4% for formal education (Eurostat, 2025)	Generative AI enters learning processes independent of policy, increasing pressure on assessment validity, integrity rules, and consistent student guidance across courses and departments.

Sources: developed by author based on (Eurostat, 2025)

The Eurostat indicators show that AI is simultaneously an economic capability driver and a ubiquitous learning input, which makes institutional governance and academic integrity safeguards unavoidable components of

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ISBN 978-9916-9320-3-2 (pdf)

digital transformation.

A second EU best-practice pillar concerns academic integrity and the redesign of assessment, because generative AI changes the cost of producing plausible text, code, and synthetic artefacts. When a substantial share of students can access generative systems, universities face a predictable integrity risk: assessment formats that primarily test production of generic written outputs become less valid measures of individual competence. Eurostat's finding that 9.4% of EU citizens used generative AI for formal education in 2025 illustrates that AI use is already present within education-related activities at scale (Eurostat, 2025). In response, EU-aligned institutional practice increasingly differentiates between acceptable learning support and unacceptable substitution, and then translates this distinction into assessment design, disclosure rules, and feedback practices. The European University Association explicitly notes the need for universities to consider AI's immediate consequences for learning and teaching and to address the ongoing innovation of learning and teaching in a responsible manner (European University Association, 2023). A deeper best practice is to treat integrity as a learning design issue rather than a detection issue. This means privileging assessment approaches that make learning processes observable, such as scaffolded assignments with draft milestones, reflective components that require justification of choices, oral defenses, in-class problem solving, and authentic tasks linked to local data or project contexts. It also involves adopting explicit AI disclosure norms that treat AI outputs as tools that must be documented, similar to how sources and methods are documented in academic work, with discipline-appropriate conventions.

Assessment resilience improves when universities articulate a limited set of institution-wide assessment patterns that remain valid under widespread availability of generative tools, while allowing disciplines to adapt details (Table 4.18).

In EU best practice, assessment redesign serves a dual purpose: it protects integrity and it upgrades learning quality, because process evidence and methodological transparency improve feedback, fairness, and competence measurement in AI-rich environments.

A third pillar is institutional accountability for AI-enabled student services and administrative processes, especially where AI could influence opportunities, resources, or progression.

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ISBN 978-9916-9320-3-2 (pdf)

Table 4.18. Assessment redesign patterns for AI-rich learning environments

Assessment pattern	What it changes	Integrity and quality benefit
Process-based assessment with milestones	Requires drafts, annotated development steps, and evidence of iteration	Reduces opportunities for last-minute substitution and improves feedback quality by making learning trajectories visible.
Oral validation and dialogic examination	Adds short oral defense or viva component for key outputs	Tests ownership of reasoning and increases validity when written outputs could be AI-assisted.
Context-specific authentic tasks	Uses local cases, datasets, or project constraints that are not easily generalised	Limits generic AI response usefulness and aligns assessment with real professional practice.
Reflective and methodological transparency	Requires students to document tool use, prompts, limitations, and verification steps	Normalises responsible AI use and builds epistemic vigilance, rather than driving AI use underground.

Sources: developed by author based on (European Parliament and Council of the European Union, 2024)

The AI Act's risk-based approach implies that the governance intensity should increase with the potential impact on individuals and with the sensitivity of processed data.

Universities therefore increasingly differentiate between AI used as a personal productivity aid by staff and AI used to support institutional decisions, such as triaging support requests, providing automated advising recommendations, or analysing student engagement data. EU-aligned accountability requires that students can understand when AI is used, what role it plays, and how human oversight operates. It also implies procurement discipline: universities must evaluate vendors' claims, data practices, and documentation, and ensure that contractual terms support transparency, auditability, and lawful processing. This governance stance aligns with the European University Association's emphasis on responsible exploration of AI tools within legal frameworks and with attention to societal consequences (European University Association, 2023). A deeper operational best practice is to implement an AI service lifecycle, including pre-deployment risk assessment, controlled pilots, post-deployment monitoring for performance and bias, incident response, and periodic review by an ethics or governance committee that includes academic and student representation.

Accountability becomes implementable when universities define a minimum control set that applies to all institutionally deployed AI use cases, with additional controls triggered by higher-risk contexts (4.19).

https://doi.org/10.36690/CIDI-EME
ISBN 978-9916-9320-3-2 (pdf)

Table 4.19. Minimum control set for institutional AI deployments in universities

Control domain	Minimum institutional requirement	Rationale in EU-aligned practice
Use-case registration and classification	Maintain an AI register with purpose, data types, users, and risk level	Enables consistent oversight and aligns governance intensity with risk-based logic (European Parliament and Council of the European Union, 2024).
Transparency and user communication	Inform students and staff when AI is used in services, including scope and limitations	Strengthens trust and reduces hidden automation, supporting institutional legitimacy.
Human oversight and appeals	Define who is accountable for decisions, and provide review and appeal pathways	Protects rights and reduces harm when AI affects opportunities or support access.
Data governance and minimisation	Specify data sources, retention, and access controls, and document lawful basis	Reduces privacy and security risk and supports compliance-oriented governance.
Monitoring and incident response	Track errors, bias signals, complaints, and performance drift; define escalation	Converts accountability into operational practice rather than policy statements.

Sources: developed by author based on (European Parliament and Council of the European Union, 2024)

EU best practice operationalises accountability by defining a common control baseline for AI deployments and escalating controls in higher-impact contexts, thereby connecting regulatory logic to day-to-day university operations.

A fourth dimension of responsible AI adoption is AI literacy as an inclusion mechanism. When AI use becomes widespread, unequal ability to use AI critically and responsibly can become a new stratification channel, where digitally advantaged students obtain disproportionate gains from AI-enabled productivity while others face higher risks of misuse, overreliance, or academic misconduct. Eurostat's evidence of significant generative AI use, including for education, suggests that the university cannot assume uniform competence or uniform access to guidance (Eurostat, 2025). EU best practice therefore treats AI literacy as a transversal competence that includes technical familiarity, critical evaluation, methodological transparency, and ethical reasoning. It is also increasingly linked to integrity education, because students require explicit instruction on verifying outputs, recognising hallucinations and bias, and documenting AI assistance in an academically acceptable way. In governance terms, AI literacy should be embedded into curricula and professional development, and supported by central services such as writing centres, digital learning units, and library-led research

https://doi.org/10.36690/CIDI-EME
ISBN 978-9916-9320-3-2 (pdf)

integrity support. This aligns with sector guidance that universities should consider AI's consequences for learning and teaching and their broader role in society (European University Association, 2023).

EU best practice on responsible AI adoption in universities is defined by the ability to govern AI as a socio-technical system across learning, research, and services. Eurostat evidence on rapid AI diffusion in enterprises and widespread generative AI use among citizens, including for formal education, implies that universities must move from informal experimentation to institution-wide governance, integrity-oriented assessment redesign, and measurable accountability controls (Eurostat, 2025). The AI Act reinforces a risk-based governance logic that supports use-case classification, transparency, and oversight, particularly where AI could affect students' rights or opportunities (European Parliament and Council of the European Union, 2024). Finally, the European University Association's position underscores that responsible AI use must align with institutional missions and values and must consider broader societal consequences, which strengthens the case for governance models that integrate ethics, law, and pedagogy rather than treating AI as a narrow technological add-on (European University Association, 2023).

5. Inclusion by design: accessibility law, disability-related participation gaps, and inclusive programme implementation. EU best practices interpret inclusion in digitally transformed universities as a binding design constraint that must be embedded into platform choices, service workflows, pedagogical models, and institutional governance. This stance is grounded in the recognition that digitalisation can simultaneously widen access and intensify exclusion when learning and services become "digital first" without systematic accessibility and support.

At the regulatory level, Directive (EU) 2016/2102 obliges public sector bodies' websites and mobile applications to be accessible, which is directly relevant for public universities that deliver admissions, enrolment, learning management, library access, and student services via digital channels (European Parliament and Council of the European Union, 2016). In parallel, Directive (EU) 2019/882, commonly referred to as the European Accessibility Act, expands accessibility requirements to a range of products and services and thereby reshapes the procurement context for educational technologies, communication tools, and service interfaces that universities purchase and deploy (European Parliament and Council of the European Union, 2019). In

https://doi.org/10.36690/CIDI-EME
ISBN 978-9916-9320-3-2 (pdf)

practical terms, EU best practice is not satisfied by isolated accommodations or reactive fixes; instead, institutions integrate accessibility requirements into governance, procurement, quality assurance, and continuous improvement cycles so that accessibility becomes structurally sustained rather than personally negotiated case by case (European Commission, 2025).

A deeper driver for inclusion by design is the empirical evidence that disability-related digital participation gaps persist in the EU and can translate into unequal access to university learning and services. Eurostat reports that in 2024, 87.2% of people with a disability had used the internet in the previous 12 months compared with 95.2% of people without a disability, indicating a non-trivial gap in baseline connectivity and digital participation (Eurostat, 2025) The same Eurostat material highlights gaps in specific “e-government type” online activities, for example interaction with public authorities, which is relevant to universities because many student services function as digital administrations where students must submit requests, provide documentation, schedule appointments, and track case progress (Eurostat, 2025). EU best practice therefore treats disability-related disparities as a governance signal: digital campuses should be designed to reduce transaction costs and cognitive load for all users, and to ensure that students who face accessibility barriers are not forced into slower, more burdensome routes to exercise their rights or receive support. This is why inclusive universities increasingly couple platform accessibility with service design principles, such as clear error handling, accessible forms, alternative contact channels, and assisted navigation, so that accessibility is realised as a lived service outcome rather than a technical compliance label (European Parliament and Council of the European Union, 2016; European Commission, 2025).

In teaching and learning, inclusion by design is typically operationalised through universal design approaches that anticipate diverse needs in content formats, assessment methods, and learning interactions. In EU best practice, accessible learning is not limited to disability accommodations, because digital inequality can be compounded by socioeconomic constraints, language barriers, remote location, and reduced institutional familiarity. As a result, institutions build inclusive digital pedagogy around multiple means of engagement and expression, accessible content authoring standards, captioning and transcription for multimedia, and structured support for time management and academic writing in hybrid contexts. This pedagogical layer must be aligned with platform governance, because even well-designed

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learning activities fail when core tools are inaccessible, unstable, or incompatible with assistive technologies. For this reason, mature universities implement accessibility checks within instructional design workflows and treat accessibility conformance as a criterion in course approval and periodic review, thereby linking inclusion to academic quality assurance rather than to voluntary individual effort.

Inclusion by design becomes implementable when legal requirements are translated into institutional controls that assign responsibility and integrate accessibility into procurement, platform management, and course quality assurance (Table 4.20).

Table 4.20. Translating EU accessibility obligations into university governance controls

EU requirement or policy direction	Practical university control	Where it is embedded	Inclusion value created
Accessibility of public sector websites and mobile apps (Directive (EU) 2016/2102)	Accessibility policy, monitoring plan, and complaint or feedback pathway for digital services	Digital governance, service management, and QA cycles	Reduces barriers in admissions, enrolment, and student services by making accessibility a baseline expectation (European Parliament and Council of the European Union, 2016).
Accessibility requirements for products and services (Directive (EU) 2019/882)	Procurement criteria that require accessibility evidence, supplier accountability, and remediation commitments	Procurement, vendor management, and contract governance	Prevents the acquisition of inaccessible tools, shifting the burden away from students and staff (European Parliament and Council of the European Union, 2019).
EU framing of accessibility as a public value	Accessibility statements and continuous improvement processes	Platform governance and communications	Improves transparency and trust, and enables iterative remediation informed by user feedback (European Commission, 2025).
Disability-related participation gaps	Inclusion KPIs that track service access and learning participation by relevant groups	Institutional analytics and student support governance	Converts inclusion into measurable performance outcomes rather than a declarative commitment (Eurostat, 2025).

Sources: developed by author based on (European Parliament and Council of the European Union, 2016; European Parliament and Council of the European Union, 2019)

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EU best practice is strongest when accessibility obligations are converted into routine controls inside procurement, platform governance, and quality assurance, because this prevents recurring exclusion and distributes responsibility from individuals to institutions.

A further dimension of inclusion by design concerns inclusive participation in transnational opportunities, particularly mobility and cooperation activities. Erasmus+ defines inclusion and diversity as programme priorities and explicitly focuses on organisations and participants with fewer opportunities, encouraging projects and activities to be designed in ways that are accessible to diverse participants (European Commission, 2025). For universities, this implies that inclusion is not only a campus issue but also a mobility issue: digital transformation should reduce administrative burden and uncertainty for students who face barriers, and should provide accessible information, application support, and reasonable adjustments during mobility preparation and participation. In best-practice settings, inclusion measures include targeted advising, accessible digital documentation workflows, pre-departure guidance in accessible formats, and financial or logistical support mechanisms that are communicated clearly and early. Importantly, these measures become more effective when linked to monitoring, for example tracking who applies, who participates, and who completes mobility, disaggregated by relevant “fewer opportunities” categories, while ensuring ethical handling of sensitive data. The strategic point is that digital inclusion and programme inclusion reinforce each other: accessible digital systems reduce friction, and inclusive programme design ensures that opportunity is not monopolised by those who already have high administrative capacity and social capital (European Commission, 2025).

Because inclusion can be unintentionally undermined by “one size fits all” digital processes, universities increasingly use a small set of indicators to detect friction points and unequal outcomes across student groups (Table 4.21).

Eurostat data support an outcome-oriented approach: universities should treat unequal access and unequal service burden as measurable risks and continuously redesign processes to reduce exclusion (Eurostat, 2025).

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Table 4.21. Disability-related digital participation evidence and monitoring implications for universities

Eurostat evidence and context	What risk it signals in a digital campus	Monitoring implication for universities
People with a disability used the internet in 2024 at 87.2% vs 95.2% without disability	Digital-first services may systematically exclude or delay access for a share of learners	Provide assisted channels and track time-to-resolution for key services to detect unequal burdens
Disability gaps in online interaction with public authorities and related activities	Transaction-heavy digital services can magnify barriers	Audit high-friction workflows such as forms, booking systems, document uploads, and case tracking, then monitor improvements
Evidence of variation by disability severity	Needs are heterogeneous and require layered support	Segment support and accessibility testing by use cases and assistive needs, not by a single “disability” category

Sources: developed by author based on (Eurostat, 2025)

Inclusion by design in EU university digital transformation combines legal compliance, evidence-informed service design, and programme-level inclusion mechanisms. The Web Accessibility Directive and the European Accessibility Act jointly imply that accessibility must be embedded into digital governance and procurement so that universities do not institutionalise exclusion through inaccessible tools and platforms (European Parliament and Council of the European Union, 2016; European Parliament and Council of the European Union, 2019). Eurostat evidence on disability-related digital participation gaps demonstrates why inclusion must be operationalised through monitoring and process redesign, especially in transaction-heavy student services and hybrid learning workflows (Eurostat, 2025). Erasmus+ inclusion priorities further show that inclusion extends to mobility and cooperation, requiring accessible communication, targeted support, and systematic tracking of participation gaps for students with fewer opportunities (European Commission, 2025). Overall, EU best practice is characterised by a shift from reactive accommodations to proactive institutional design, where accessibility and equity are treated as core quality conditions of the digital university.

Conclusion. EU best practices show that university digital transformation should be governed as a coherent institutional reform rather than implemented through isolated technology projects. The most robust models begin with a clear operating structure that assigns decision rights, aligns investments with strategic priorities, and embeds assurance for quality, security, and ethics. Interoperability becomes a strategic capability when mobility and credential services are redesigned as end-to-end public services supported by common standards, trusted identity layers, and verifiable credentials. Capacity building is the main condition of success, because unequal entry-level digital readiness, uneven staff preparedness, and shortages of advanced specialists can quickly undermine both quality and inclusion. Responsible AI adoption requires universities to treat AI as a socio-technical system that affects assessment validity, student trust, and procedural fairness, so governance must include risk classification, transparency, human oversight, and continuous monitoring. Inclusion by design strengthens the legitimacy of transformation when accessibility is built into procurement, platform governance, course design, and service workflows, and when participation gaps are tracked as performance risks. Overall, the EU approach integrates innovation and cohesion by translating values into measurable controls that protect rights, widen opportunity, and support cross-border cooperation.

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Conclusions

This monograph has examined digital transformation as a systemic and multidimensional phenomenon shaping management, leadership, entrepreneurship, business models, territorial development, markets, and educational institutions under conditions of heightened uncertainty and prolonged external threats. The analysis demonstrates that digitalization and artificial intelligence are not merely technological processes, but deeply institutional, socio-economic, and strategic transformations that redefine development trajectories in crisis-affected economies.

1. The study carried out analyzed e-government as a central mechanism of public sector digitalization and demonstrated that it functions not only as a technological upgrade but as a structural modernization of administrative management. The study conducted a systematic examination of how electronic platforms, automated workflows, and data-driven tools reshape interactions between the state, citizens, and business by improving service speed, transparency, and accessibility. The study also analyzed the conditions that determine implementation success and identified that infrastructure readiness, regulatory adaptation, cybersecurity, and the digital literacy of both civil servants and citizens are decisive enabling factors. The study examined the practical relevance of integrated service ecosystems and showed that platforms such as Diia illustrate how unified digital services can reduce bureaucracy, lower administrative burden, and strengthen civic engagement through digital participation tools. At the same time, the study identified persistent constraints, including unequal access to connectivity, resistance to change in institutions, and heightened exposure to cyber threats. The study concluded that effective digital transformation requires a comprehensive strategy that combines technology deployment with staff training, performance monitoring through clear indicators, and the development of a supportive digital culture. The study conducted outlined future-oriented priorities, including expansion of AI and blockchain applications, stronger trust and data protection mechanisms, and continuous capacity building to sustain long-term governance improvements.

2. The study carried out examined digital transformation as a systemic shift that combines technology adoption, process redesign, and capability development, and it clarified that its managerial significance lies in changing

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how organizations generate value, coordinate work, and make decisions. The study conducted analyzed how artificial intelligence, social media, and ICT can expand women's leadership pathways by increasing visibility, strengthening networks, enabling flexible work models, and creating new entrepreneurial entry points, including in regional and rural contexts. The study also analyzed persistent constraints and established that structural bias, unequal access to digital skills, limited access to finance, and weak support ecosystems can reproduce gender inequality even in technologically advanced environments. The study carried out systematized the key mechanisms linking digital transformation and women's leadership and demonstrated that positive outcomes depend on governance choices that translate technology into fair procedures, transparent promotion criteria, and accountable inclusion practices. The study conducted concluded that women's leadership functions as a strategic resource for innovation, sustainability, and resilience, but its potential becomes operational only when organizations ensure equal access to tools, training, and capital. The study analyzed implications and determined that coordinated interventions at firm and ecosystem levels are required to align digital transformation strategies with measurable inclusion outcomes and long-term competitiveness.

3. The research undertaken interpreted organizational security as an integrated management framework that aligns physical protection, information safeguards, and economic stability to ensure operational continuity, minimize losses, and constrain internal weaknesses. The analysis showed that personnel loyalty operates as a security-significant behavioral asset manifested in managerial trust, adherence to internal regulations, commitment to organizational objectives, and intentions to remain with the employer. The study revealed a mutually reinforcing linkage whereby coherent security policies strengthen perceptions of justice, predictability, and managerial capability, while loyalty mitigates insider threats and supports orderly, rule-based performance. The research examined how physical safety measures serve as an observable marker of organizational responsibility, how information protection cultivates a compliance climate grounded in trust, and how financial resilience sustains confidence in employment stability and organizational reliability. The study determined that security effectiveness should be tracked through clear metrics, including incident rates, training reach, compliance breaches, response timeliness, payroll regularity, turnover patterns, and proactive risk reporting. The analysis also emphasized the

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facilitating role of public governance by demonstrating that regulatory certainty, monitoring mechanisms, support tools, and the spread of security competencies reduce uncertainty and strengthen internal controls. The study concluded that security-focused management is most effective when it is systemic, data-informed, and continuously refined through audits, feedback loops, and organizational learning, thereby enhancing resilience and long-term sustainability.

4. The study undertaken examined foreign economic activity as a strategic factor that strengthens enterprise resilience, competitiveness, and organizational maturity amid volatile demand, logistical disruptions, and intensified international rivalry. The study showed that engagement in external markets broadens revenue streams, improves utilization of production capacity, and reduces dependence on local business cycles, while simultaneously increasing exposure to currency volatility, contractual disputes, regulatory differences, and counterparty default risk. The study conducted conceptualized the management of foreign economic activity as an integrated governance architecture rather than a collection of separate deals, and it distinguished strategic, tactical, and operational levels to specify responsibilities, control procedures, and expected results. The study analyzed how process discipline, documentary correctness, logistics synchronization, and settlement supervision shape the predictability and scalability of cross-border operations, and it emphasized that financial outcomes cannot be evaluated reliably without complementary process and risk indicators. The study determined that digitalization enhances managerial capability by ensuring traceability, standardization, and prompt feedback, thereby enabling continuous oversight and timely corrective interventions. The study also concluded that artificial intelligence can strengthen decision support through forecasting, anomaly detection, and scenario modeling, provided that accountability, legal compliance, and final judgment remain under human control.

5. The study conducted a theoretical and comparative examination of tax instruments shaping the development of digital entrepreneurship in Ukraine under conditions of prolonged external pressure. The study demonstrated that digital business models, due to the dominance of intangible assets, rapid scalability, and high mobility, respond primarily to institutional signals embedded in taxation, especially regulatory predictability, administrative simplicity, and perceived equity. The study found that simplified taxation

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regimes facilitate market entry, encourage formalization, and strengthen short-term robustness by reducing compliance burdens and easing liquidity constraints. At the same time, the study identified an entry–scaling tension, because extended dependence on simplified regimes can discourage corporatization, reinvestment, capital deepening, and movement toward higher value-added activities, thereby sustaining structural fragmentation of the sector. The study analyzed Diia.City as a scaling-oriented policy instrument and concluded that its potential advantages are contingent on institutional credibility, legal stability, transparent administration, and consistent enforcement practices. The study also determined that crisis-related relief and deferral measures operate as stabilizers that support survival, yet they must be integrated into a sequenced policy approach that creates clear pathways toward investment and innovation-oriented regimes. Finally, the study showed that European integration dynamics and international tax coordination reduce the scope for discretionary incentives, making gradual, rule-based alignment essential for long-term competitiveness.

6. The study undertaken substantiated that the full-scale war and the subsequent reconstruction agenda have transformed digitalization in construction from an optional modernization vector into an operational requirement that conditions sectoral resilience and the effectiveness of recovery programs. The study established that construction plays a systemic role in national renewal due to its tight interconnection with real and financial markets, which amplifies the multiplier effect of digital tools on productivity, transparency, and sustainability. The study identified a set of restraining determinants, including low digital readiness of firms, fragmented implementation of solutions, dispersed investment resources, and an underdeveloped organizational and economic framework for managing digital change. The study also clarified the ambivalent nature of digitalization, which simultaneously generates efficiency gains and increases managerial complexity, thereby requiring coordinated governance, financing, and capability building. The study developed an assessment logic grounded in a four-component interaction model linking the state, regions, higher education institutions, and the business environment, and integrated this logic with organizational life-cycle diagnostics to capture phase-specific crises and transition needs. The study proposed an improved integral mechanism that differentiates stability levels of digitalization and supports risk forecasting and strategic choice. Overall, the study concluded that comprehensive, lifecycle-

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sensitive, and multi-level coordination is essential for accelerating construction digitalization and strengthening post-war reconstruction capacity.

7. The study conducted conceptualized post-war tourism recovery in Ukraine as a transformation agenda in which digitalization and UAV innovations operate as complementary drivers of resilience, sustainability, and sectoral renewal. The analysis demonstrated that the tourism sector is showing measurable signs of revitalization, which creates a policy window for reconfiguring destination management toward safer, more data-driven, and experience-enhancing models. The research examined how digital tools can restructure the tourism value chain, while UAVs can expand the informational and narrative capacity of destinations through mapping, documentation, monitoring, and immersive content generation. The study identified that UAV-enabled applications are especially relevant for heritage recording, environmental stewardship, and strategic marketing, thereby supporting both cultural continuity and ecological responsibility. The study also assessed the diffusion logic of UAV adoption and determined that institutional and regulatory constraints, security-driven airspace management, and public concerns about privacy remain decisive barriers. The analysis outlined pronounced regional differentiation, indicating that implementation pathways must be adapted to security conditions, reconstruction intensity, and local administrative capacity. The study formulated strategic directions that integrate governance frameworks, dedicated financing, regional innovation hubs, interoperable data platforms, and workforce training. Overall, the study concluded that coordinated, ethically grounded, and regionally tailored UAV-driven digitalization can accelerate tourism recovery while strengthening long-term sustainability and community-centered development.

8. The study carried out conceptualized ICT markets under external military pressure as socio-technical systems in which technological infrastructures, institutional orders, geopolitical interdependence, and behavioural mechanisms interact and jointly determine sectoral stability. The analysis demonstrated that military threats generate multi-domain, intentional disruptions that differ from ordinary crises by combining kinetic damage, cyber aggression, informational manipulation, and uncertainty shocks. The study examined infrastructural vulnerability and established that attacks on concentrated nodes and interdependent networks can trigger cascading failures, while recovery tends to be temporally asymmetric and structurally

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coercive. The research analyzed cyber and hybrid operations and found that they destabilize ICT markets not only through technical harm but also through trust erosion, expectation volatility, and increased compliance burdens. The study assessed market dynamics and identified differentiated trajectories: contraction in consumer and general enterprise segments alongside accelerated growth in cybersecurity, cloud redundancy, and defense-oriented technologies. The analysis investigated human capital and supply chains and showed that displacement, cognitive strain, and import dependence generate path-dependent capacity loss. The study also evaluated governance conditions and found that emergency mandates, inter-agency fragmentation, and cloud jurisdiction dilemmas weaken regulatory coherence. Overall, the study concluded that resilience requires integrated action across infrastructural distribution, cybersecurity architecture, diversified supply strategies, protected talent pipelines, adaptive regulation, and international coordination.

9. The study conducted examined artificial intelligence as a general purpose technology that reshapes competitive dynamics through pervasive spillovers, continuous performance improvement, and strong complementarities with data, human expertise, and digital infrastructure. The analysis demonstrated that AI functions as a competitiveness catalyst by activating technological mechanisms of automation and prediction, organizational mechanisms of learning and coordination, market mechanisms of differentiation and scalability, and institutional mechanisms linked to transparency and compliance. The study analyzed AI as a strategic resource and established that sustained advantage emerges when algorithms are embedded in firm-specific data assets, path-dependent training routines, and governance architectures that are difficult to replicate. The research identified mechanism-based pathways of competitive impact, showing how efficiency, intelligence, autonomy, scalability, and strategic disruption jointly create persistent performance gradients across firms and sectors. The study examined adoption trajectories and showed that competitive asymmetry intensifies across maturity phases, because early movers accumulate compounding data advantages, talent concentration, and feedback-driven learning effects. The analysis also determined that value creation expands through AI-enabled business model archetypes, including intelligent products, platform orchestration, and data monetization, while institutional competence and ethical governance moderate the sustainability of gains. Overall, the study concluded that AI-driven competitiveness depends on coherent integration of

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technology, organizational design, human capital, and governance into a continuously adaptive capability system.

10. The study carried out developed and conceptually validated an integrated approach that links economic resilience, information security, and web developer competence in European IT enterprises. The analysis demonstrated that cybersecurity exposure and financial vulnerability increase when recruitment and workforce development focus on programming performance while neglecting secure coding behavior, regulatory literacy, and risk-aware decision making. The study examined the implications of talent shortages and high turnover and established that these pressures amplify latent vulnerabilities, raise remediation costs, and weaken continuity when secure development practices are not embedded from onboarding onward. The research conducted structured modeling of risk categories, maturity levels, and competency clusters and showed that multi-level learning systems function as a preventive mechanism that reduces vulnerability density, compliance failure probability, and post-deployment rework. The study also analyzed the role of automated assessment and concluded that algorithm-supported screening improves hiring speed and consistency only when security-critical competencies are explicitly measured and aligned with organizational governance. The findings confirmed that the highest readiness is achieved when HR analytics, secure SDLC practices, and investment planning operate as a single decision architecture. Overall, the study concluded that secure recruitment and continuous learning are strategic levers that strengthen cyber resilience, optimize cybersecurity spending, and support sustainable competitiveness in the EU digital market.

11. The study conducted a comprehensive strategic assessment of the sustainable development prospects of Ukrainian higher education institutions by combining PEST-based macroenvironment evaluation with an expert SWOT analysis for state and private universities. The analysis demonstrated that political and regulatory factors generate predominantly negative pressure through policy volatility and frequent regulatory changes, while economic and social factors produce the strongest constraints via financial instability, demographic decline, and migration of applicants and academic staff. The study carried out an expert consistency check and confirmed a sufficiently high level of agreement, which strengthened the reliability of the synthesized cognitive map and the subsequent interpretation of factor interactions. The results obtained indicated that technological development and digitalization

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act as the most influential supportive drivers, because they enable new teaching formats, management efficiency, and wider access to educational services. The study identified that international cooperation, grant funding, and integration into the European educational space represent the most significant opportunities for both university types. At the same time, the research revealed differentiated strategic positions: the state university was shown to require horizontal diversification that leverages competitive strengths to withstand external threats, whereas the private university was found to need an anti-crisis trajectory focused on internal auditing, cost optimization, program alignment with labor market needs, and partnership expansion. Overall, the study concluded that sustainable development in Ukrainian higher education depends on adaptive strategy selection, coordinated modernization, and systematic balancing of opportunities against persistent external risks.

12. The study examined European best practices in university digital transformation and identified that the most effective approaches treat digitalisation as an institutional reform rather than a sequence of disconnected technology projects. The analysis demonstrated that governance capacity is decisive, because clear operating models, portfolio management, and assurance mechanisms align strategy, delivery, and quality control while reducing fragmentation. The study established that interoperability functions as a strategic public service capability when mobility and credential processes are redesigned end to end, supported by consistent data governance, trusted identity and status validation, and verifiable digital credentials. The study also found that skills and capacity building represent the main constraint of transformation, since uneven student readiness, educator preparedness, and shortages of advanced specialists can undermine both learning quality and organisational performance. The research highlighted that responsible AI adoption requires risk-based institutional controls, including use case registration, transparency, human oversight, monitoring, and assessment redesign that prioritises process evidence and methodological disclosure. The study concluded that inclusion by design strengthens legitimacy when accessibility is embedded in procurement, platforms, course design, and service workflows, and when participation gaps are monitored as measurable risks.

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